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EVALUATION OF COMMERCIALLY AVAILABLE OPEN CIRCUIT SCUBA REGULAT--ETC(U)
MAR 80 J R MIDDLETON

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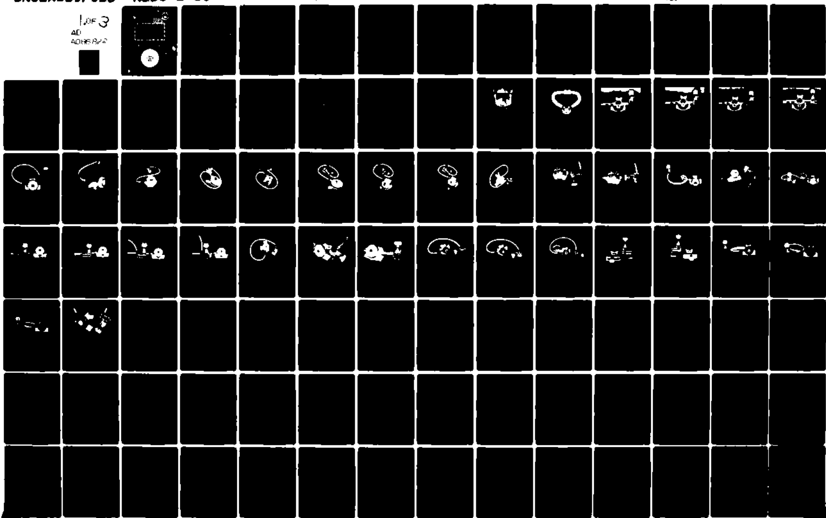

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407

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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 2-80

EVALUATION OF COMMERCIALLY AVAILABLE OPEN CIRCUIT SCUBA REGULATORS

JAMES R. MIDDLETON

MARCH 1980

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Scuba Regulator	Exhalation	Breaths per Minute (BPM)
Breathing Resistance	Breathing Work	
Breathing Cycle	Tidal Volume	
Inhalation	Respiratory Minute Volume (RMV)	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In June 1979 the Navy Experimental Diving Unit performed unmanned tests on 36 open circuit scuba regulators currently manufactured in the United States. Breathing resistance, respiratory work and first stage performance were evaluated. Results of these tests produced a new NEDU scuba regulator performance requirement to replace the current requirement taken from Mil-R-24169A. Of the 36 regulators tested, 7 regulators met the upgraded performance standard, 22 regulators and one full face mask met Mil-R-24169A, and 6 regulators did not meet Mil-R-24169A.

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Glossary

Terms	Definition
ANU	Authorized for Navy Use
BPM	breaths per minute
cm H_2O	centimeters of water pressure
cracking pressure	inhalation effort in cm H_2O required to initiate flow on demand from the scuba regulator
fsw	feet sea water
EDF	Experimental Diving Facility
kg·m/l	breathing work in kilogram meters per liter ventilation
L.P.	low pressure
LPM	liters per minute (flow rate)
mil spec	military specification Mil-R-24169 (Regulator, Air, Demand, Single Hose, Non-Magnetic, Divers 22 March 1967)
NEDU	Navy Experimental Diving Unit
O/B	over bottom pressure
ΔP	pressure differential
psid	pounds per square inch differential
psig	pounds per square inch gauge
RMV	respiratory minute volume in liters per minute (BPM x tidal volume)
tidal volume	the volume of gas inhaled or exhaled in one breath
USN	United States Navy

Abstract

In June 1979 the Navy Experimental Diving Unit performed unmanned tests on 36 open circuit scuba regulators currently manufactured in the United States. Breathing resistance, respiratory work and first stage performance were evaluated. Results of these tests produced a new NEDU scuba regulator performance requirement to replace the current requirement taken from Mil-R-24169A. Of the 36 regulators tested, 7 regulators met the upgraded performance standard, 22 regulators and one full face mask met Mil-R-24169A, and 6 regulators did not meet Mil-R-24169A.

I. INTRODUCTION

In June 1979, NEDU tested all scuba regulators currently manufactured in the United States. The regulator manufacturers and models are listed in Table 1.

The state of the art in scuba regulator design has improved significantly in the last 4 years. The vast majority of regulators currently produced meet or exceed existing NEDU performance requirements based on Mil-R-24169A (see Figure 1). Consequently, the evaluation of all available regulators during one test sequence was initiated to develop an upgraded NEDU performance requirement based upon state of the art equipment.

A single regulator of each model style was purchased through commercial distributors. The testing of several copies of each model was both unfeasible and unnecessary. Each unit was calibrated to factory specifications for second stage cracking pressure and first stage intermediate O/B pressure prior to testing. This procedure is performed by all Navy activities at regular intervals and ensured that each regulator was tested under the same conditions. Performance during this evaluation is therefore indicative of the actual design and quality control limitations of the unit uninfluenced by improper set-up procedures.

The NEDU performance requirement which resulted from these tests was based soley upon identifying a group of regulators whose performance, at maximum normal operating depths and moderately severe work rates, was significantly superior to the other units evaluated. The data was analyzed and a specific group of seven regulators demonstrated superior performance at and beyond 132 fsw and 62.5 RMV. Maximum respiratory work level for these regulators at 132 fsw and 62.5 RMV was 0.14 kg·m/l. The next closest regulator outside this group has a work level of at least 0.16 kg·m/l. From a physiological viewpoint respiratory work levels considerably higher than 0.16 kg·m/l have been tolerated. However, the value of 0.14 kg·m/l at 62.5 RMV and 132 fsw has been accepted as the performance criteria (see Figure 2) since it represents the point at which the difference between state of the art and more conventional regulator performance becomes significant.

In the past, breathing resistance rather than breathing work has been used as the primary criteria for regulator evaluations. However, although the data is meaningful, peak respiratory pressures on inhalation and exhalation do not provide as complete a definition of total performance as does the work of breathing measurement. A complete discussion of breathing work, breathing resistance, first stage performance and the relationship of the three is covered under Results and Discussion.

All tests were conducted using established NEDU Unmanned Test Procedures. The regulators were tested at five RMV's to simulate light through extreme diver work rates at each depth, thus defining a complete performance profile on each regulator under all possible operating conditions. In addition to breathing resistance and work, first stage intermediate pressure losses under dynamic flow conditions were recorded. Consequently, regulator performance, be it excellent or poor, could be assessed as a function of either a first stage design, second stage design or a combination of both.

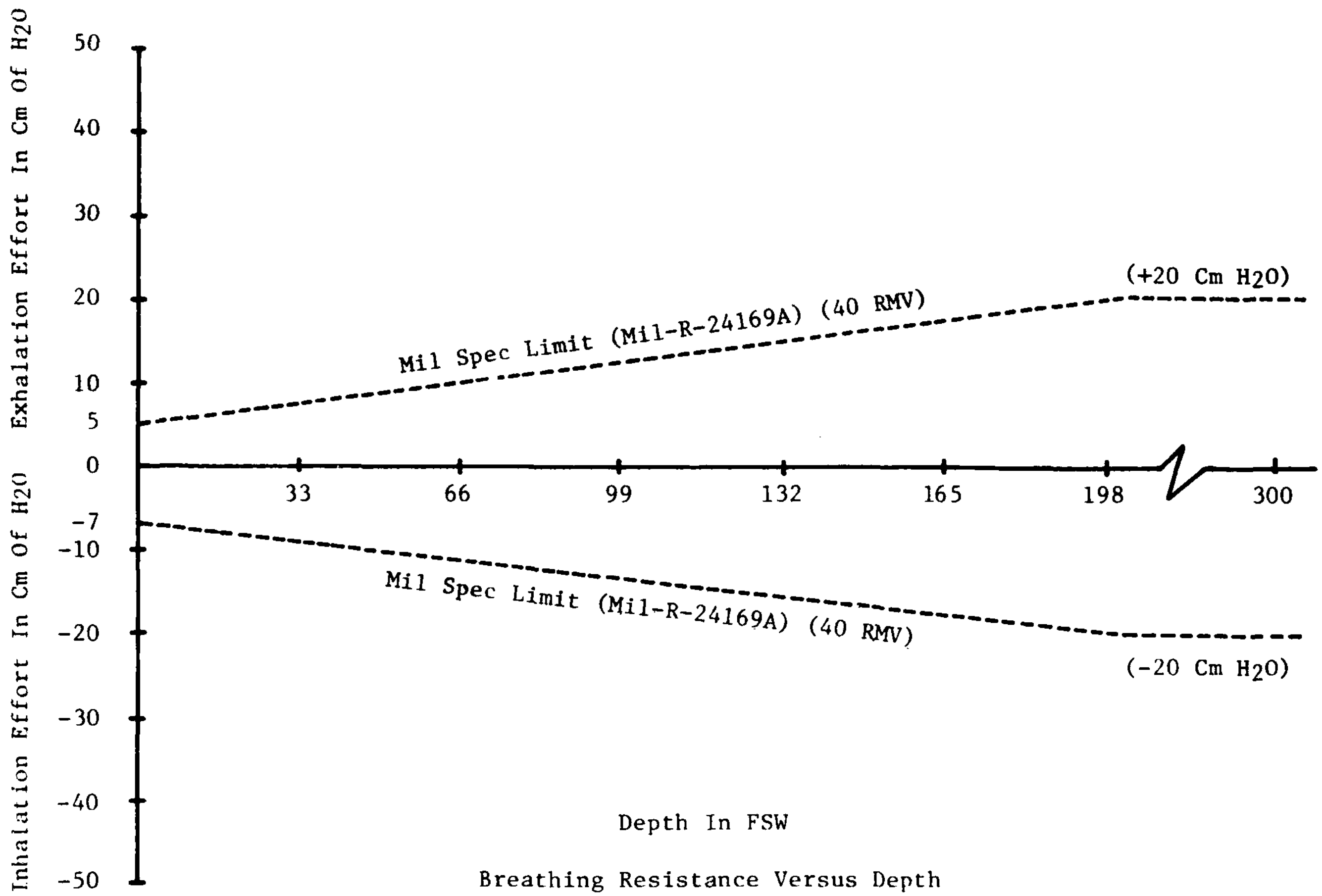


Figure 1. Previous NEDU scuba regulator performance requirement at 40 RMV

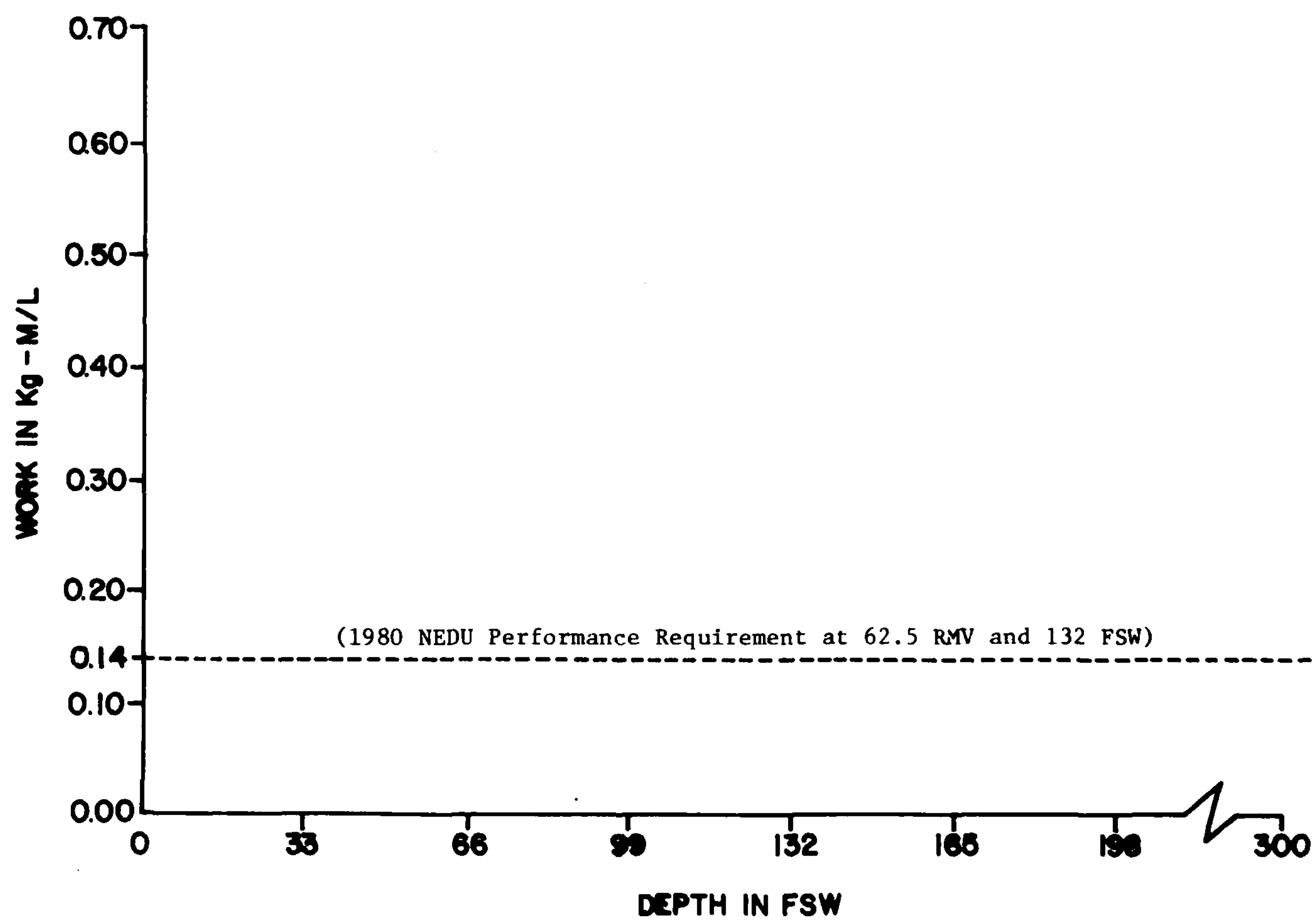


Figure 2. 1980 NEDU scuba regulator performance requirement

II. TEST PROCEDURE

A. Test Plan

NEDU test equipment was set up as shown in Figure 3 and all testing of the subject regulators was conducted in accordance with established NEDU unmanned test procedures. The actual test plan is given in Appendix A. A breathing machine simulated diver inhalation and exhalation at various depths. The instrumentation and test equipment shown in Figure 3 is listed in Appendix B. Parameters controlled, measured, computed and plotted are listed below.

B. Controlled Parameters

The following parameters were controlled:

(1) Breathing Rate / Tidal Volume / RMV / Simulated Diver Work Rate

- (a) 15 BPM / 1.5 liters / 22.5 LPM / Light
- (b) 20 BPM / 2.0 liters / 40.0 LPM / Moderate
- (c) 25 BPM / 2.5 liters / 62.5 LPM / Moderately Heavy
- (d) 30 BPM / 2.5 liters / 75.0 LPM / Heavy
- (e) 30 BPM / 3.0 liters / 90.0 LPM / Extreme

(2) Exhalation/Inhalation time ratio: 1.00/1.00

(3) Breathing waveform: sinusoid

(4) First stage gas supply pressure: 1000 psig at all depths, 500 psig and 300 psig at 0, 99 and 198 fsw

(5) Supply gas: air

(6) Incremental depth stops: 0 to 198 fsw in 33 fsw increments and 300 fsw

C. Measured Parameters

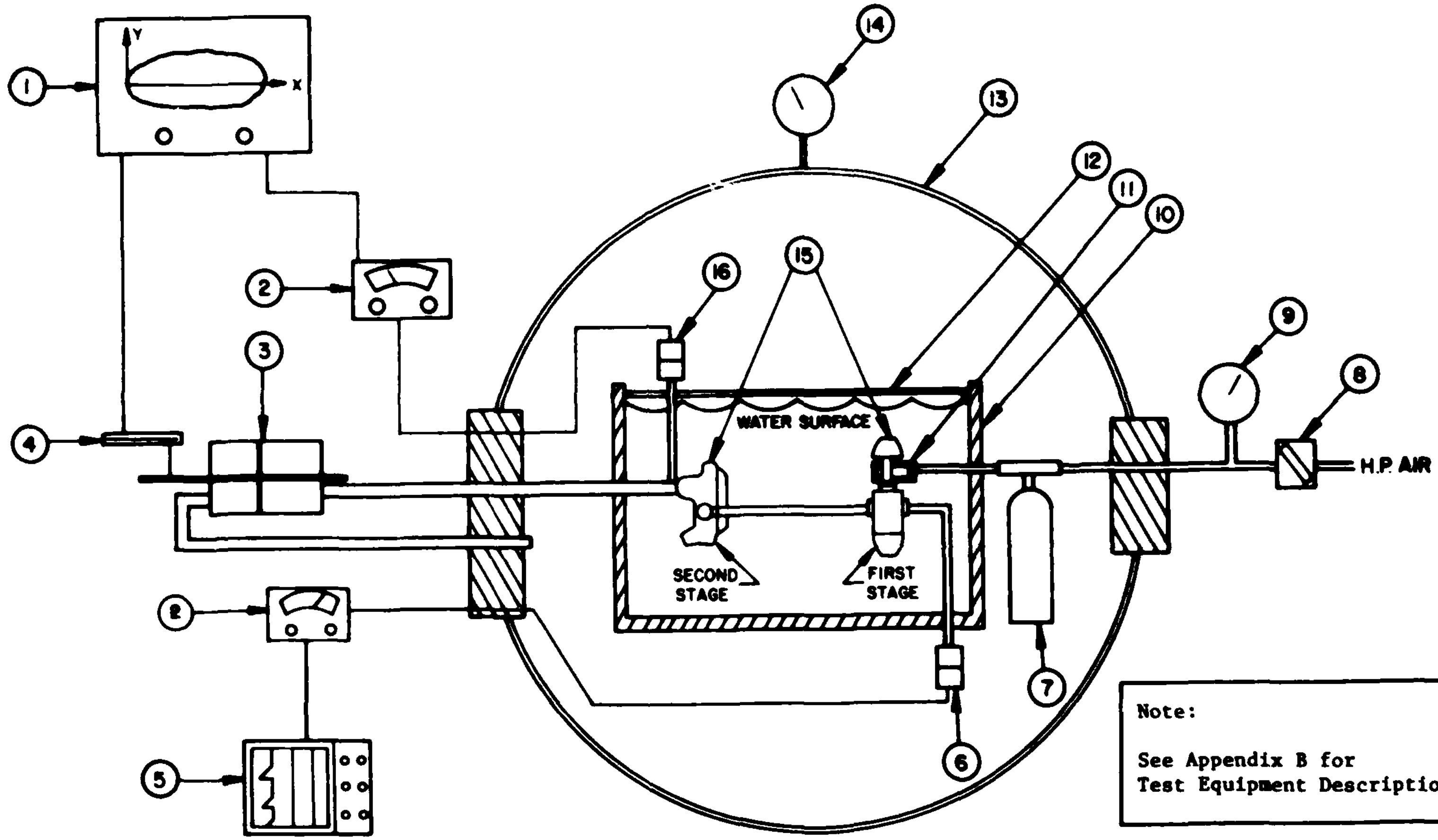
The following parameters were measured:

(1) Inhalation maximum ΔP

(2) Exhalation maximum ΔP

(3) ΔP vs. tidal volume plots

(4) Dynamic first stage intermediate pressure drop



Note:

See Appendix B for
Test Equipment Description

1. X-Y Plotter
2. Transducer Readout
3. Breathing Simulator
4. Piston Position Transducer
5. Strip Chart Recorder
6. First Stage Pressure Transducer (200.0 psid)
7. Scuba Tank
8. Pressure Regulator
9. Air Supply Pressure Gauge
10. Wet Test Box
11. Standard Scuba Tank Valve
12. Bubble Dampening Mat
13. Chamber Complex
14. Depth Gauge
15. Test Regulator (1st and 2nd Stage)
16. Oral Pressure Transducer (1.00 psid)

Figure 3. Test Setup

D. Computed Parameters

Respiratory work is computed from ΔP vs. tidal volume plots.

E. Data Plotted

The following data are plotted in this report.

(1) Inhalation maximum ΔP vs. depth at each RMV tested

(2) Exhalation maximum ΔP vs. depth at each RMV tested

(3) Respiratory work vs. depth at each RMV tested

(4) Dynamic first stage intermediate pressure drop vs. depth at each RMV tested

III. RESULTS AND DISCUSSION

A. Description

Table 1 is a list of the manufacturers represented in this report, given in alphabetical order. Following Table 1 is a picture and description of each regulator tested. The description of each regulator was supplied by the manufacturer and reflects those features he feels to be significant and unique to his product.

TABLE 1. LIST OF MANUFACTURERS

AGA Corporation, Divator Division
1163 Chess Drive, Suite G
Foster City, California 94404
(415) 574-1826

AMF Voit Swimaster
3801 South Harbor Boulevard
Santa Ana, California 92704
(714) 546-4220

Dacor Corporation
161 Northfield Road
Northfield, Illinois 60093
(312) 446-9555

Jepsen Company
3570 Warrensville Center Road
Cleveland, Ohio 44122
(216) 752-3290

Poseidon Systems
241 Raritan Street
South Amboy, New Jersey 08879
(201) 721-5301

TABLE 1. (Continued)

Scubamaster
P. O. Box 8030
233 E. Manville Street
Compton, California 90220
(213) 636-0846

Scubapro USA
3105 E. Harcourt
Compton, California 90221
(213) 639-7850

Seapro, Inc.
18030 South Euclid Street
Fountain Valley, California 92708
(714) 979-6730

Sherwcod Selpac
120 Church Street
Lockport, New York 14094
(716) 433-3891

Sportsways
2050 Laura Avenue
P. O. Box 2407
Huntington Park, California 90255
(213) 587-4173

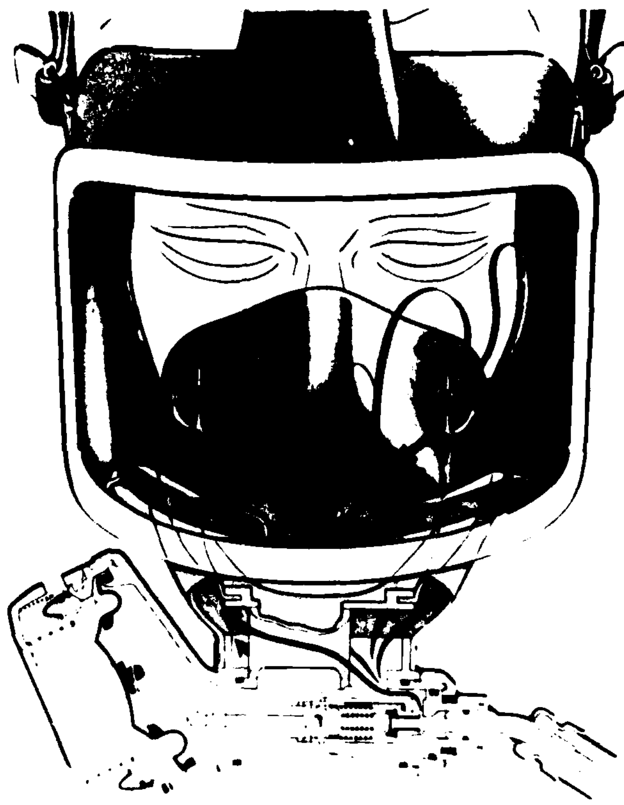
Sub Aquatic Systems
530 Sixth Street
Hermosa Beach, California 90254
(213) 379-2491

Tekna
3549 Haven Avenue
Menlo Park, California 94025
(415) 365-5112

U. S. Divers Company
3323 West Warner Avenue
Santa Ana, California 92702
(714) 540-8010

White Stag Water Sports
P. O. Box 5308
Carson, California 90749
(213) 538-9540

A. Regulators



AGA Divator 324

The AGA Divator 324 Full Face Mask incorporates a free flow valve, purge valve and 90° non-return valve, and is designed to permit low opening pressure and high capacity with low breathing resistance. It is constructed of high impact polycarbonate, selected synthetics, stainless steel and rubber components, all of which are impervious to sea water, extremes of heat and cold and concentrations of chemicals. There are no metal to metal contacts, prohibiting build up of salts and oxides.

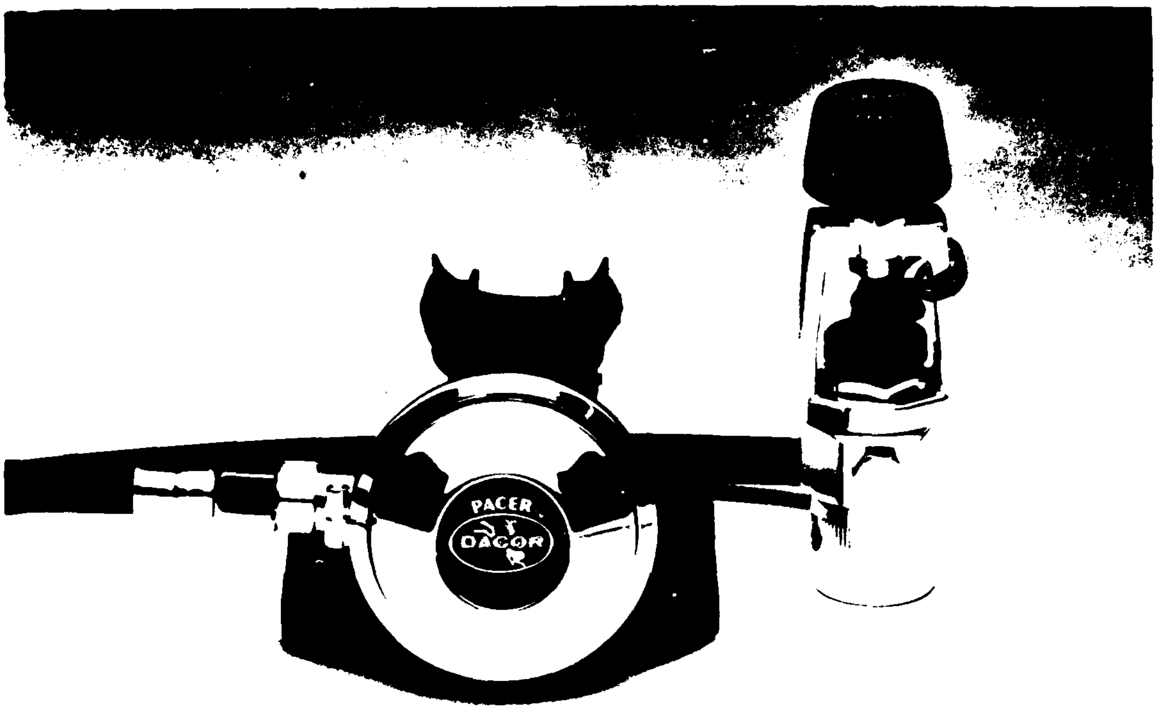
The AGA Divator 324 Full Face Mask was tested in conjunction with a U. S. Divers Conshelf XIV first stage regulator.

A. Regulators (Continued)

Dacor C3NB

The C3NB is a two hose, two stage balanced regulator with triple plated chrome brass parts. The hose features bacteria resistant neoprene with true spiral and an off-set mouthpiece. Internal mechanism has Teflon coated H.P. seat, free floating second stage seat, and low modular diaphragms for low breathing effort.

A. Regulators (Continued)

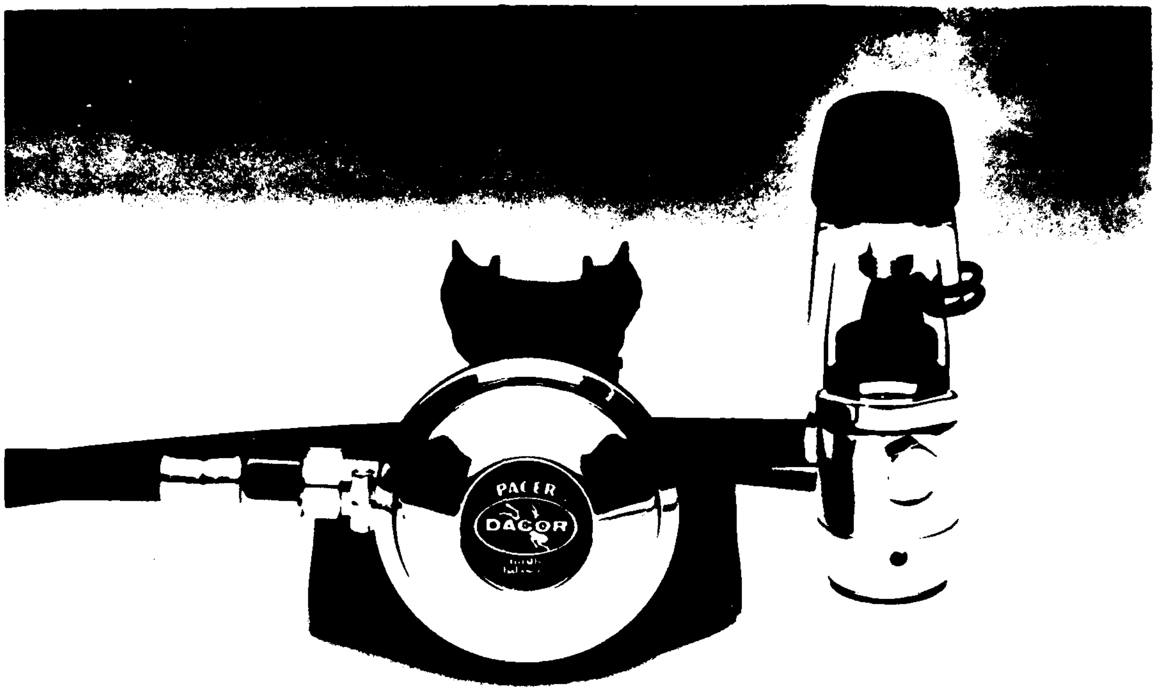


Dacor Pacer 150

The Pacer 150 offers a piston spring design first stage with a high pressure seat and heavy duty swivel yoke.

The second stage is the same as that used with the Pacer 900.

A. Regulators (Continued)

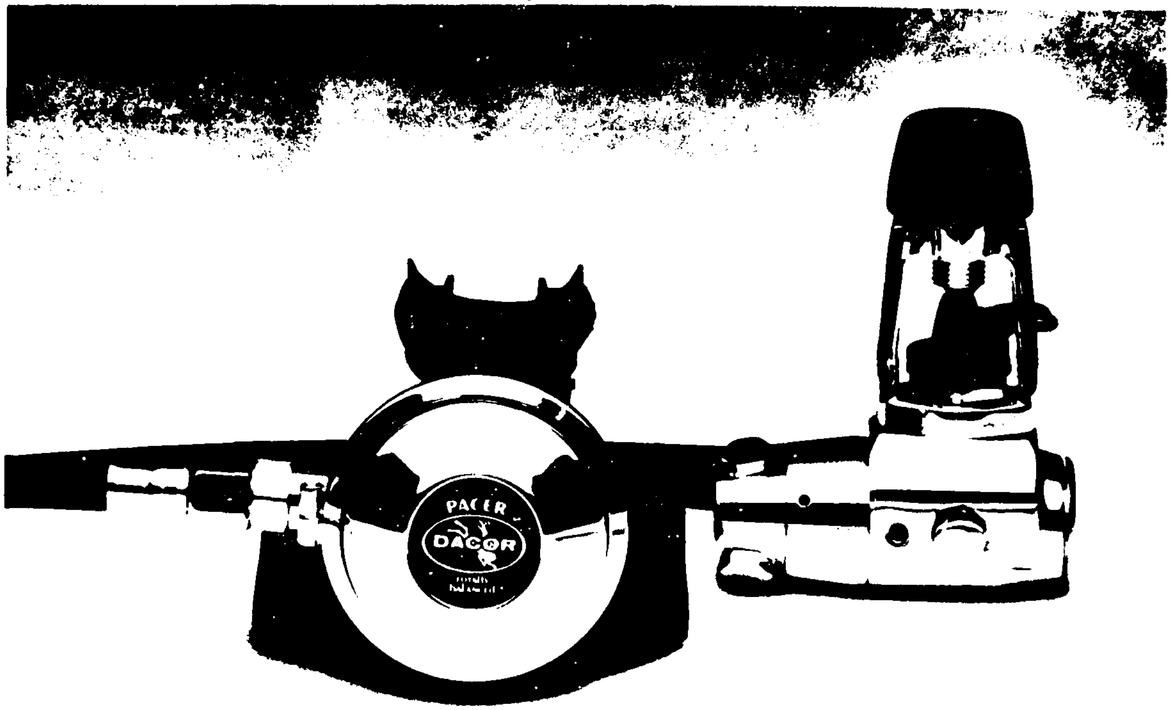


Dacor Pacer 300

The Pacer 300 balance chamber uses a high pressure diaphragm and seat, and features two low pressure ports and a heavy duty swivel yoke.

The second stage is the same as that used with the Pacer 900.

A. Regulators (Continued)

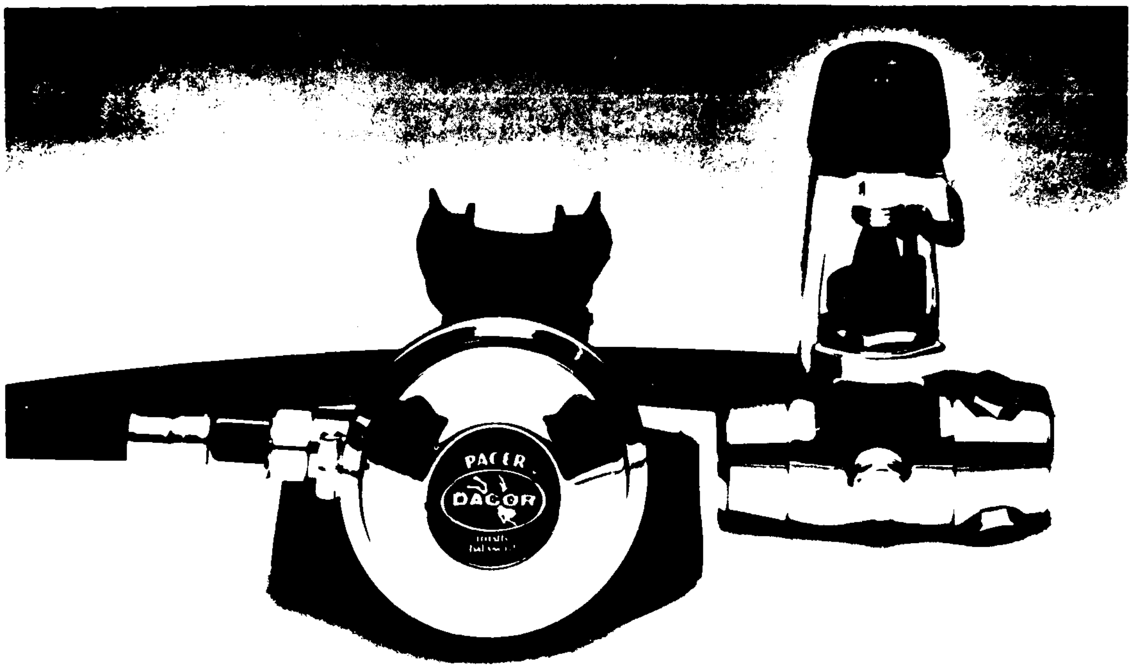


Dacor Pacer 600

The Pacer 600 is a balanced piston design first stage with a Teflon high pressure seat. There are two high pressure ports, and three low pressure ports on a swivel.

The second stage is the same as that used with the Pacer 900.

A. Regulators (Continued)

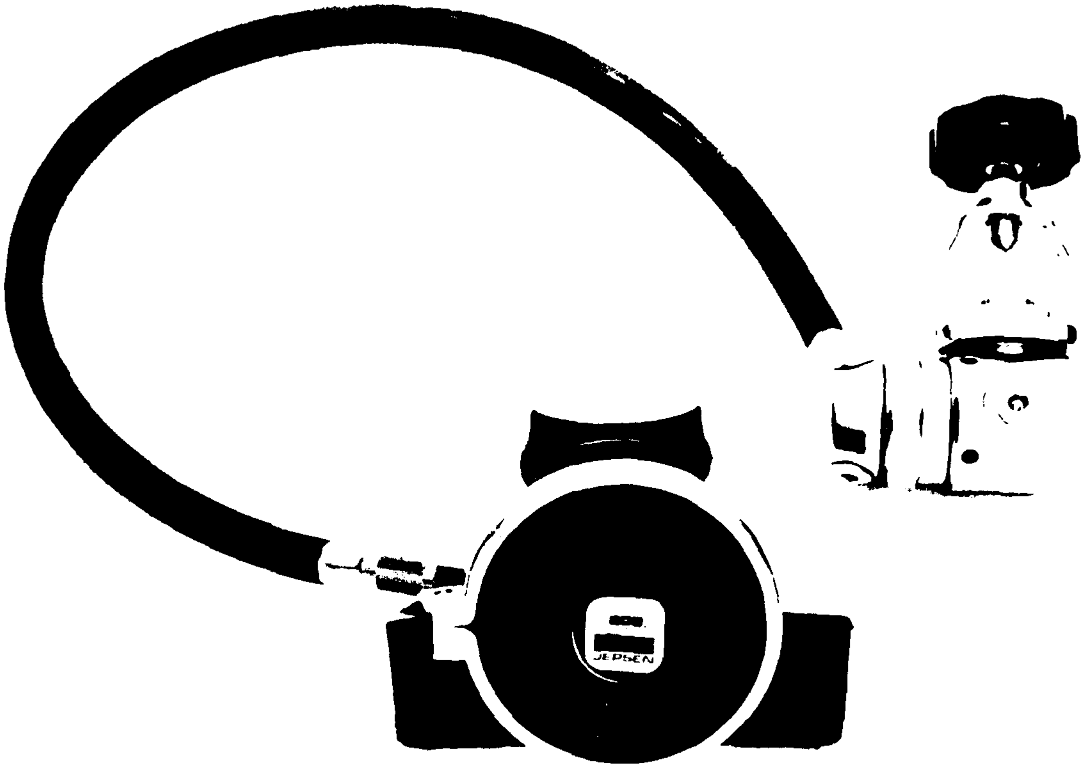


Dacor Pacer 900

The Dacor Pacer 900 features a high pressure module with balanced high pressure diaphragm and seat. There are two high pressure ports and three low pressure ports, the latter located on a swivel.

The second stage uses a flow vane on the demand lever for air balancing, and an anti-free flow device with a special water chamber to balance ambient water pressure on the internal side of the diaphragm and stop free flow. A neoprene diaphragm is used with a bonded stainless steel plate for added wear at the contact point with the demand lever activator. Two exhaust ports are utilized to lower exhalation breathing resistance.

A. Regulators (Continued)

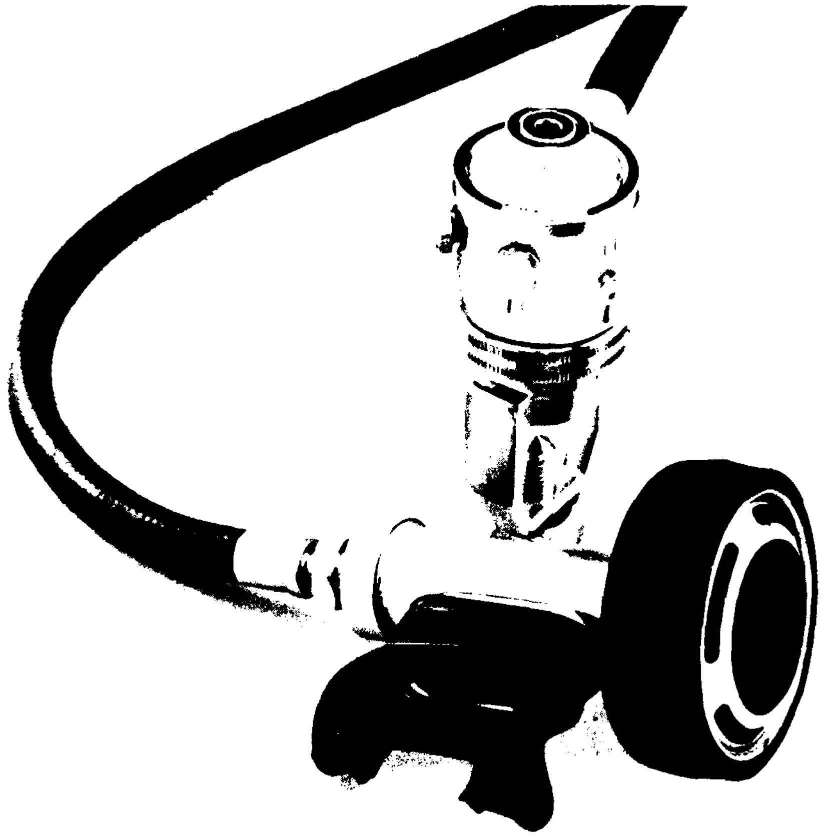


Jepsen Model 200

The Jepsen 200 first stage features three low pressure ports for attachment of a primary and auxiliary demand regulator. A balanced flow-through stainless steel piston design also provides two high pressure ports for mounting of a high pressure gauge in any regulator mounting position.

The second stage features an adjustable orifice with silicone rubber valve head. The housing is a lightweight cycoloc with silicone diaphragm and exhaust valves.

A. Regulators (Continued)



Poseidon Cyclon 300

The Poseidon first stage offers three low pressure ports and one high pressure port. It is easily adaptable for freeze proofing and handles any tank pressure up to 4400 psi. The Poseidon fits European non-yoke tanks and adapts to the French yoke.

The nine ounce second stage exhales off to the side, and is easy to repair and tune.

A. Regulators (Continued)

Scubamaster Model 7687

The Scubamaster first stage is a pressure-balanced diaphragm design with adjustable intermediate pressure and an encapsulated seat. It features one high pressure and three low pressure ports.

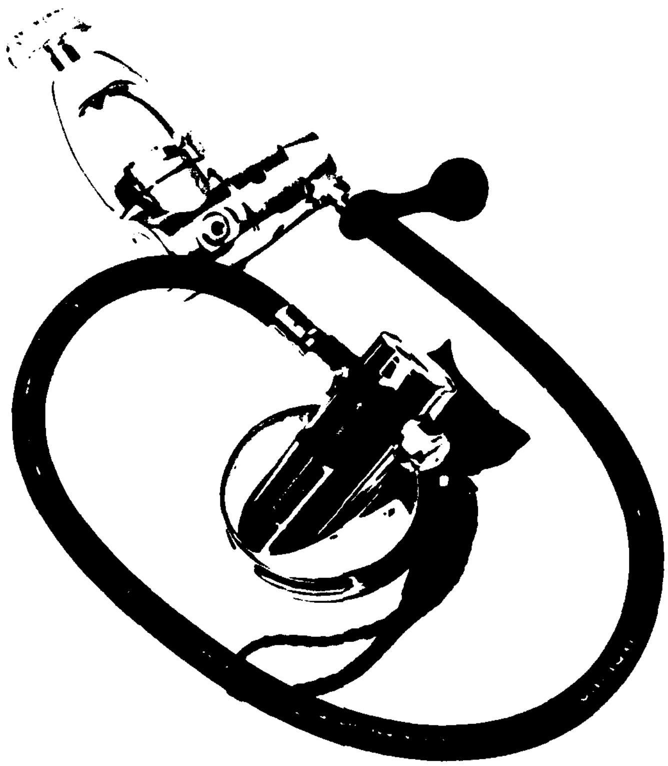
The second stage is a vortex-assisted high volume air delivery system with a Variable Exhaust Balance to enhance inhalation by balancing exhalation resistance. The diaphragm and exhaust valve are constructed of silicone, and the demand lever button is Teflon-tipped for smooth operation.

A. Regulators (Continued)

Scubapro Mk V (4-Port Swivel)

The balanced Mk V features a large first stage piston with a high flow rate capability, and an adjustable second stage. These are coupled through a multiple swivel connection with four low pressure ports for variable positioning of the tank valve. Two high pressure ports allow pressure gauge to be positioned on either side of the diver. The second stage is the externally adjustable 109 Model.

A. Regulators (Continued)



Scubapro Pilot/Mk V (4-Port Swivel)

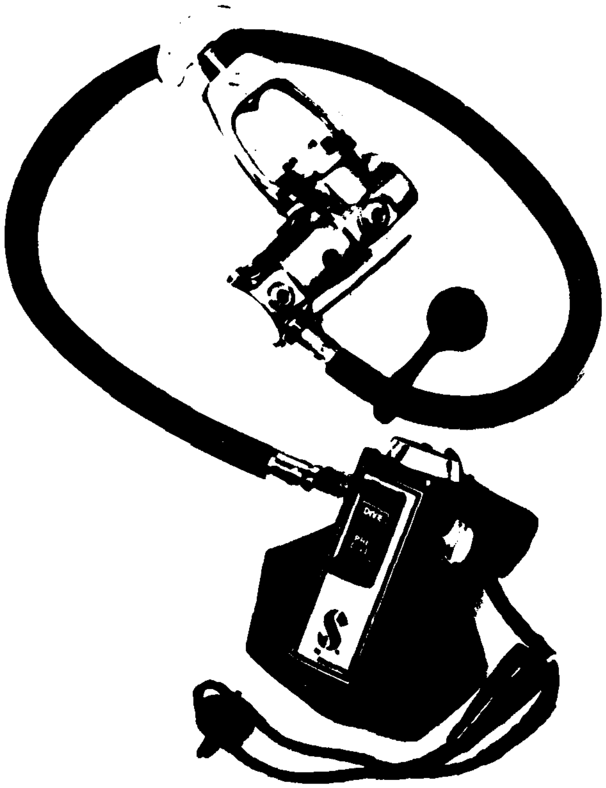
The Pilot is a servo operated second stage, pneumatically amplified for natural, automatic breathing with low resistance. Natural breathing controls the pilot valve which delivers full air pressure demanded from the first stage. The Pilot has a "pre-dive" switch that can be activated to prevent free-flow during surface swimming or other situations that benefit by decreasing the regulator's response. The Pilot can be used with any first stage. Dual inlet ports allow a choice of connections: right or left-handed regulator, octopus rig, or double with two first stages. The Pilot weighs ten ounces and is constructed of chrome plated brass. The Mk V first stage has the same basic features as the Mk V (4-Port Swivel) previously discussed.

A. Regulators (Continued)

Scubapro Mk V (5-Port Swivel)

This first stage regulator is the same as the Mk V (4-Port Swivel) with an added low pressure port. The second stage is the externally adjustable 109 Model.

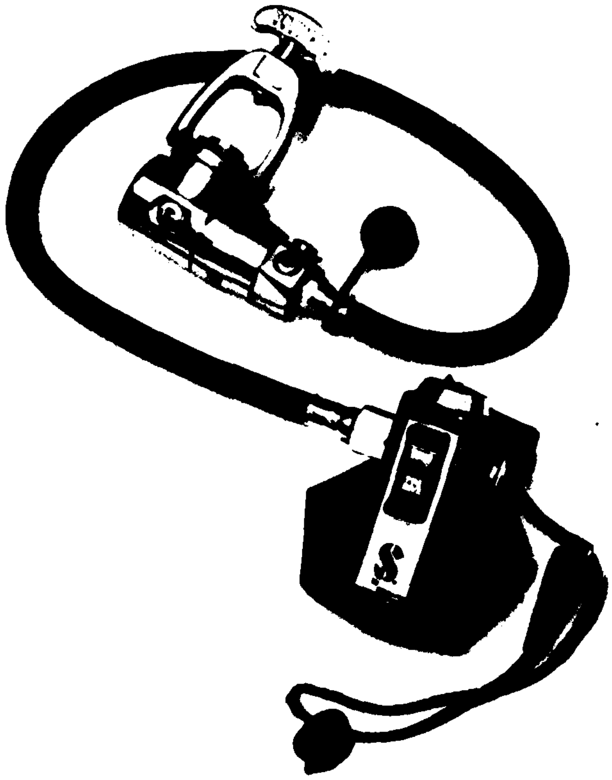
A. Regulators (Continued)



Scubapro Air I/Mk V (4-Port Swivel)

The Mark V first stage is coupled with Scubapro's newest second stage. The light weight second stage offers a simple internal design to provide easy breathing and low maintenance. It is designed for right or left-handed installation, and features a non-corrosive, low-profile design.

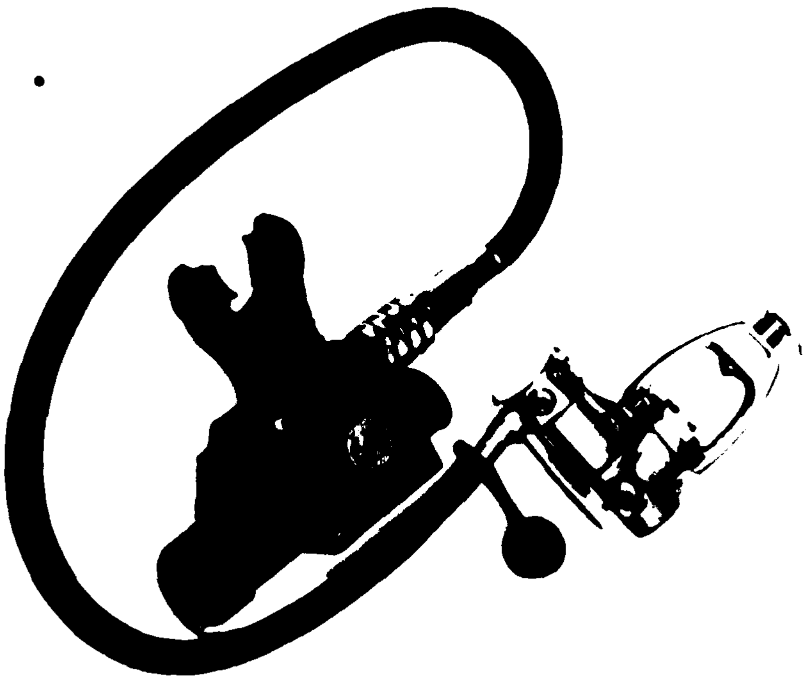
A. Regulators (Continued)



Scubapro Air I/Mk V (5-Port Swivel)

This regulator configuration is the same as the Air I/Mk V (4-Port Swivel) with an added low pressure port.

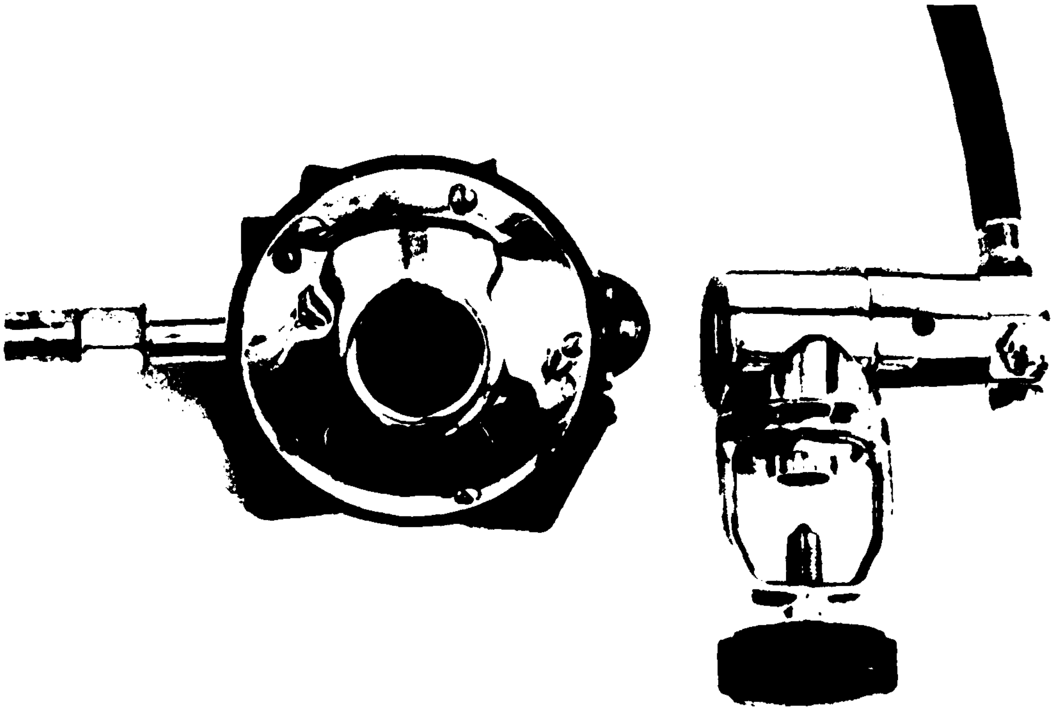
A. Regulators (Continued)



Scubapro Air II/Mk V (4-Port Swivel)

The Mark V (4-Port Swivel) first stage is coupled with a uniquely designed second stage which combines the features of a buoyancy compensator inflator and an emergency regulator. It is mounted to the buoyancy compensator in the same manner as the quick-release L.P. inflator and incorporates a high-flow, one-handed quick-release. This regulator is not designed to be the diver's main source of breathing air.

A. Regulators (Continued)

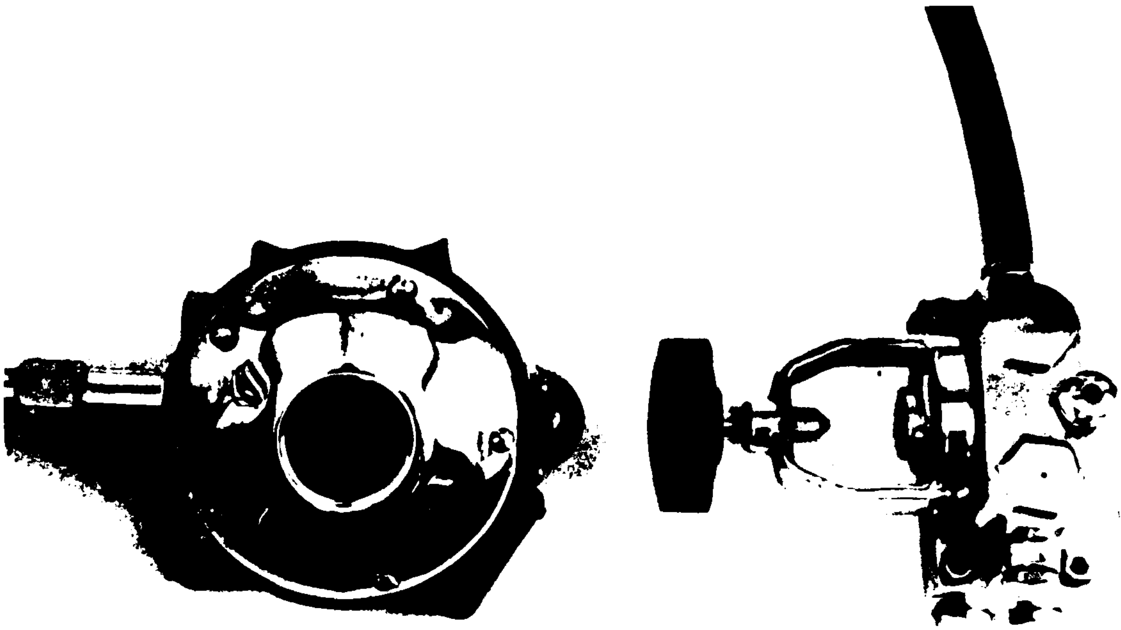


Seapro FSDS-10

The FSDS-10 first stage is a flow through balanced piston design and has a 360 degree swivel with four low pressure ports. It is constructed of chrome plated brass and stainless steel, with a corrosion resistant stainless steel spring.

The second stage is the same as that used with the FSDS-50.

A. Regulators (Continued)



Seapro FSDS-50

The FSDS-50 first stage is a twin piston design to provide fail safe operation, and includes an integral reserve mechanism with manual reserve overide. The first stage lowers the pressure of the tank air into two independent intermediate levels (about 170 psi and 110 psi above local ambient). The regulator is constructed of chrome plated brass and stainless steel, and uses a corrosion resistant stainless steel spring.

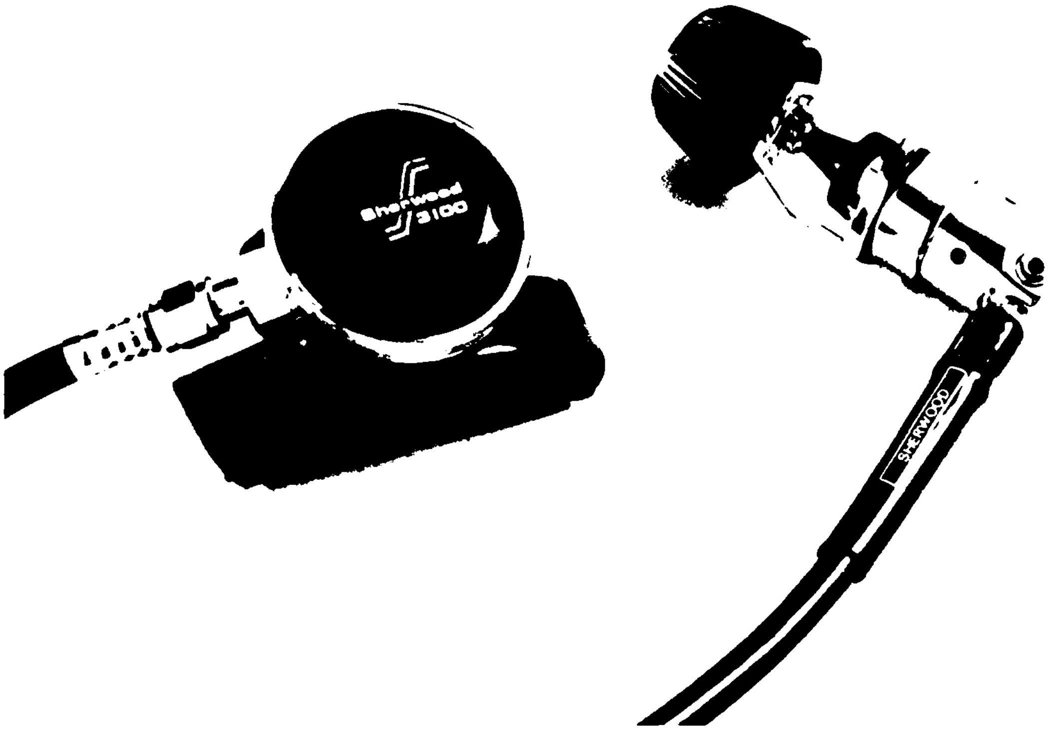
The second stage is a downstream valve design which uses intermediate supply pressure to assist valve opening, and acts as a relief valve if the first stage should leak. A low shore silicone rubber diaphragm is used for minimum breathing effort.

A. Regulators (Continued)

Sherwood Selpac SRB-2000

The first stage regulator features a heavy duty swivel yoke, a large piston that offers quick breathing response, three low pressure ports for auxiliary attachments, and one high pressure port with a safety orifice to prevent high pressure hose whip. The regulator has a minimum number of parts to simplify maintenance and cleaning. The second stage utilizes the same components as all Sherwood regulators.

A. <u>Regulators</u> (Continued)



Sherwood Selpac SRB-3100

The Sherwood SRB-3100 is a balanced piston regulator assembly for service up to 3500 psig. Most first and second stage parts are interchangeable with the SRB-4100. The SRB-3100 features four low pressure ports, one high pressure port, forged swivel yoke, and balanced piston design to keep interstage pressure constant down to reserve level.

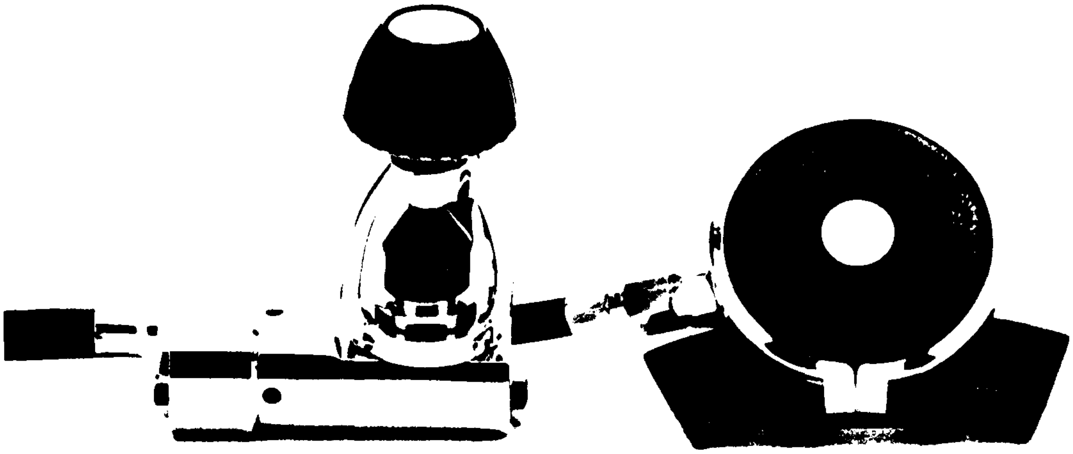
The second stage features a housing of thermoplastic resin with spin off bezel for ease of cleaning. A push-lock prevents second stage bezel movement in use.

Sherwood Selpac SRB-4100

The Sherwood SRB-4100 uses a balanced piston design to keep breathing effort level constant until air supply drops to reserve level. The regulator handles 4000 psig service pressure, and has four low pressure ports. A modular design allows rapid replacement or regulator modification by any dive shop.

The second stage features a large diameter silicone exhaust valve, patented variable fulcrum lever and air foil case design for inhalation assist.

A. Regulators (Continued)

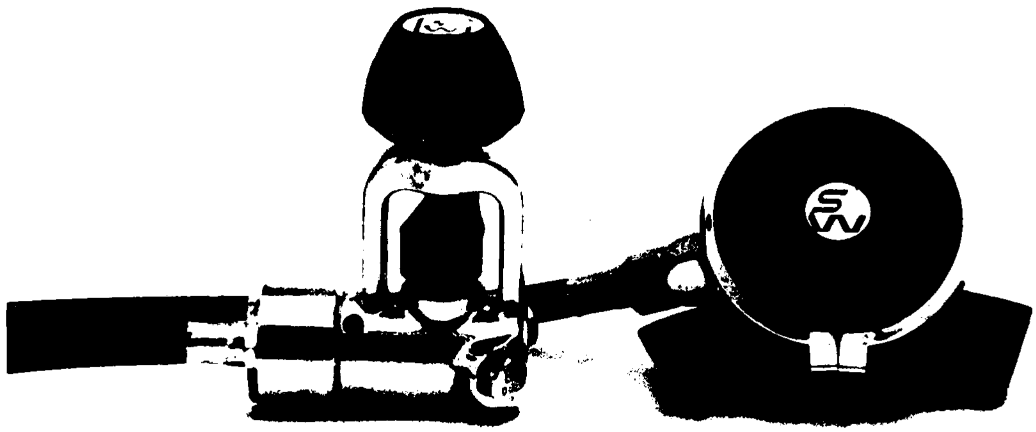


Sportsways Waterlung WL-200

The Sportsways first stage is a balanced piston assembly constructed of stainless steel and features an extra high pressure port.

The ten ounce second stage has an extra large purge valve, built flush to the housing for easy clearing, and a 1-1/8 inch exhalation port. The diaphragm is of environmental-proof silicone, and the housing is constructed of corrosion proof Lexan. This second stage is the same used on all Sportsways regulators.

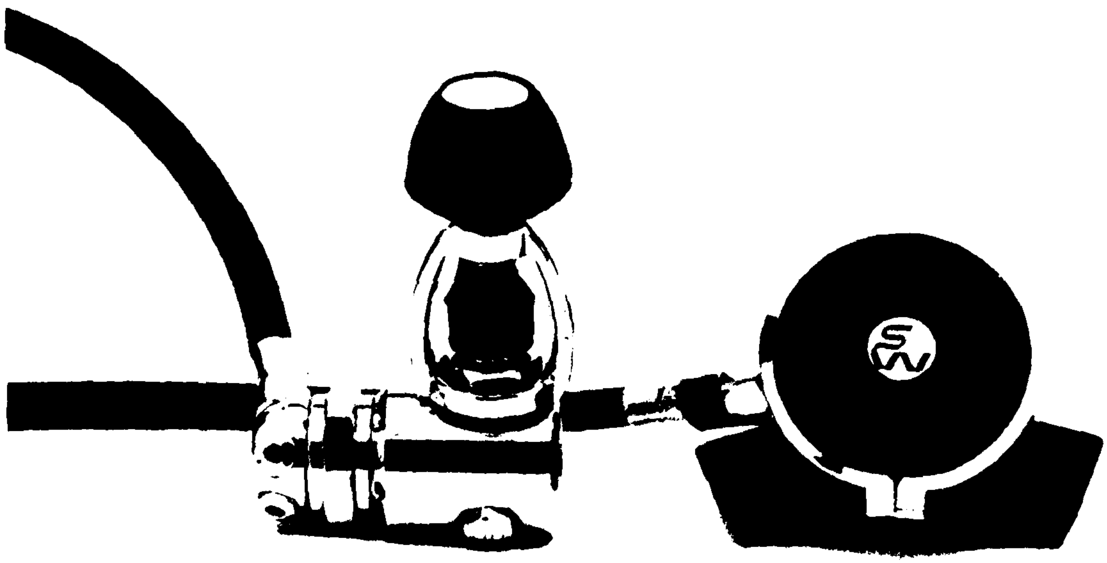
A. Regulators (Continued)



Sportsways W-600 Hydronaut

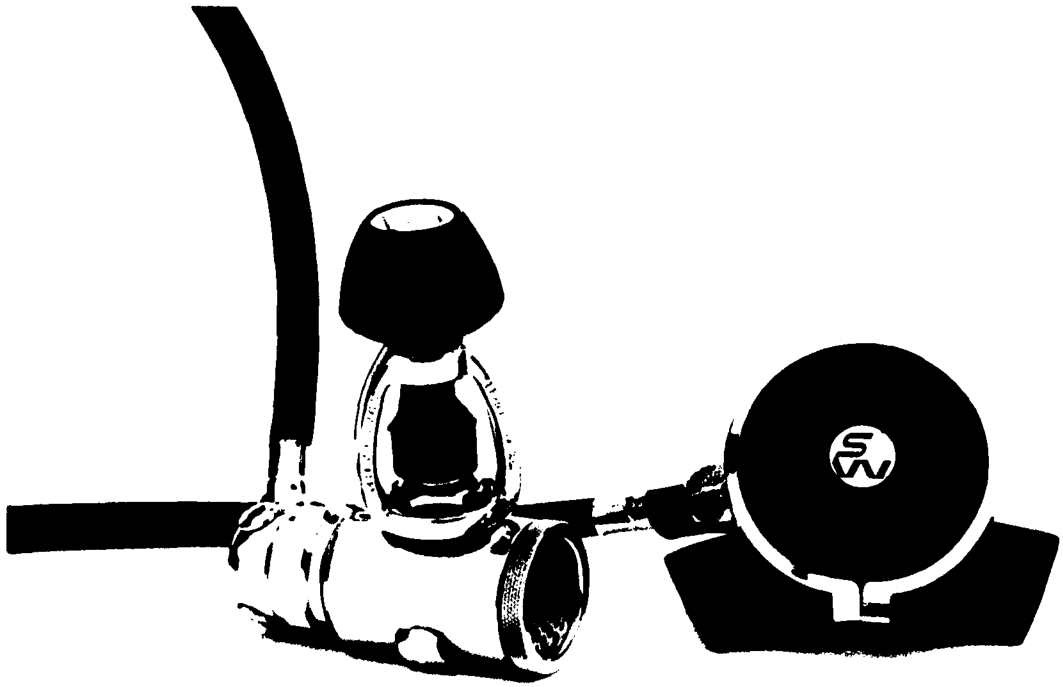
The W-600 is a fully balanced flow through piston first stage with all the features of the W-200, plus an additional low pressure port specifically for buoyancy compensator power inflation. Three additional low pressure ports are located in the end cap. This regulator services up to 4000 psi.

A. Regulators (Continued)



Sportsways W-900 Waterlung

This regulator offers all the features of the W-950 except for the oil-filled closed system design. It provides service to 4000 psi.

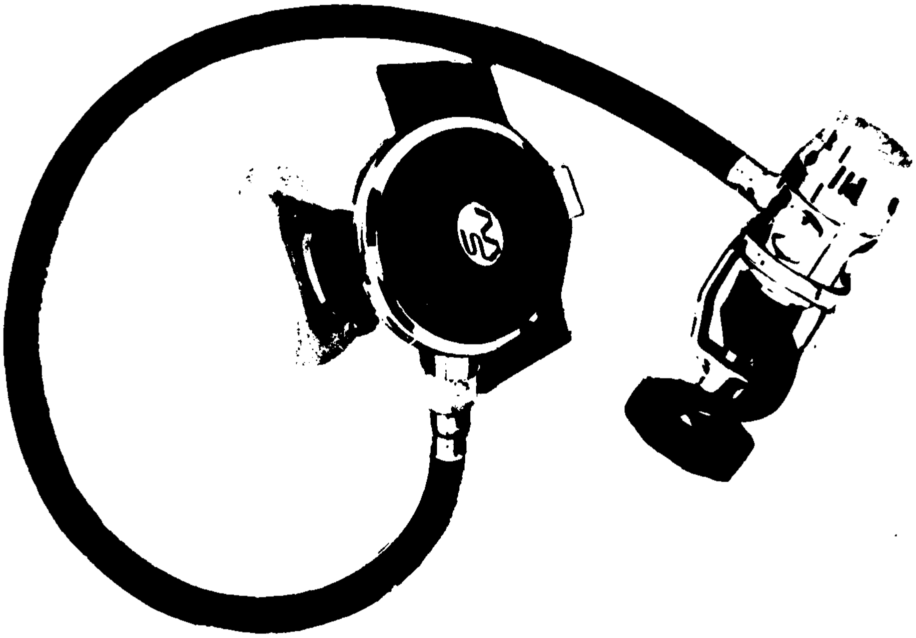


Sportsways W-950 Arctic

The W-950 first stage is fully balanced, with a stainless steel flow-through piston, a Teflon wiper backing up the O-ring seal, and a reversible and replaceable Teflon high pressure seat. It is an oil-filled and sealed design to prevent fouling from foreign particles. Two high pressure ports have different sized threads than the low-pressure ports to prevent accidental attachment of low pressure accesories. A swivel end cap contains the four low pressure ports. The W-950 utilizes a forged swivel brass yoke for service to 4000 psig.

The second stage features a floating piston orifice for minimum maintenance, an extra thin diaphragm, and a nylon insert on the demand lever. The 1-1/4 inch exhaust valve is constructed of an environmentally resistant compound, and extra large ports in the exhaust tee help minimize exhalation effort. The housing is made of corrosion proof resin.

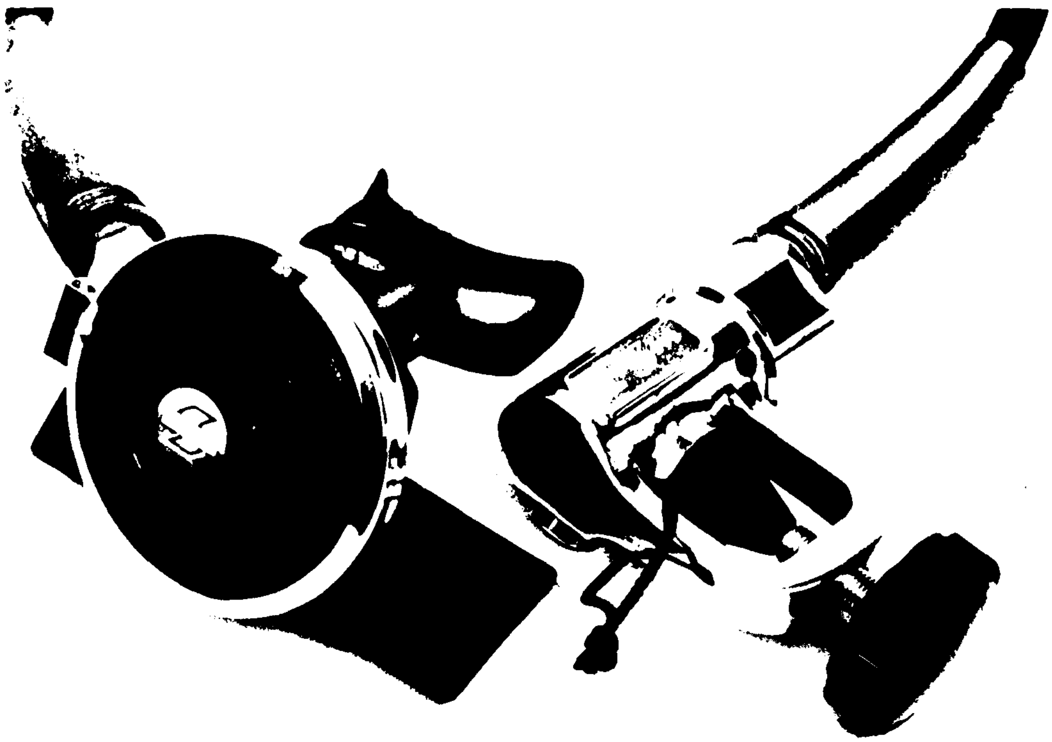
A. Regulators (Continued)



Sportsways Model 1390

The 1390 features a pre-set piston type first stage, and a second stage with a simple design for ease of maintenance.

A. Regulators (Continued)



Sub Aquatic Systems Sub II

A balanced first stage, stainless steel flow-through piston, and reversible high pressure seat minimize maintenance; three low pressure ports, and one high pressure port are standard. The second stage features a Cycolac housing with a downstream adjustable orifice valve, a silicone diaphragm and exhaust valve.

The second stage is the same as that used with the Sub X.

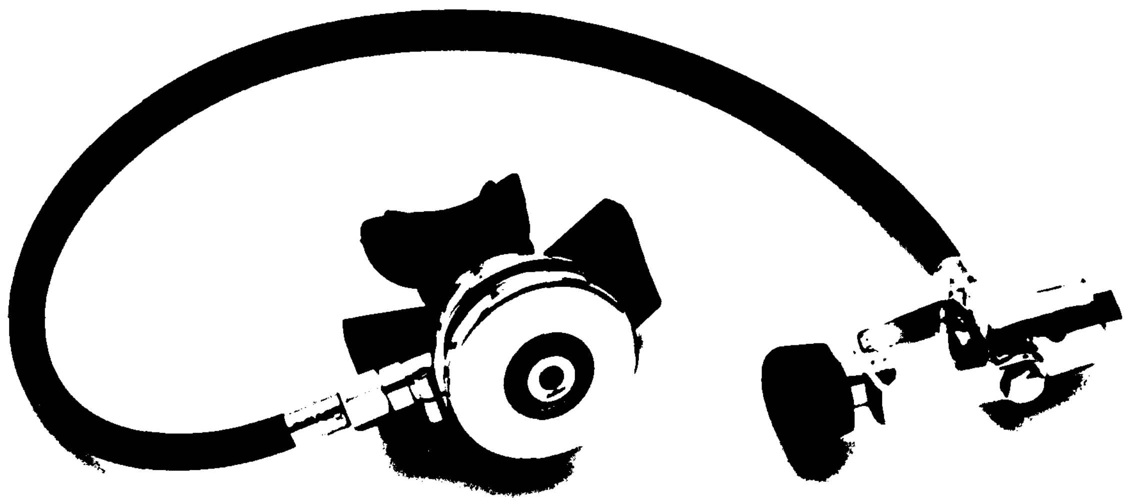
A. Regulators (Continued)

Sub Aquatic Systems Sub X

A balanced first stage, stainless steel flow-through piston and reversible high pressure seat minimize maintenance of the Sub X. This air delivery regulator features a high pressure swivel with four angled ports. The two high pressure ports are engineered for proper routing of the air monitor no matter what position the air delivery regulator is mounted in. The second stage has a downstream adjustable orifice valve allowing easy breathing and minimizing free-flow problems. The cover/case is molded, high strength, corrosion free, Cycolac. It features a silicone diaphragm and exhaust valve for easier breathing.

The second stage has a Cycolac housing with a downstream adjustable orifice valve, a silicone diaphragm and exhaust valve. The total weight of the second stage is only 9 ounces for less jaw fatigue.

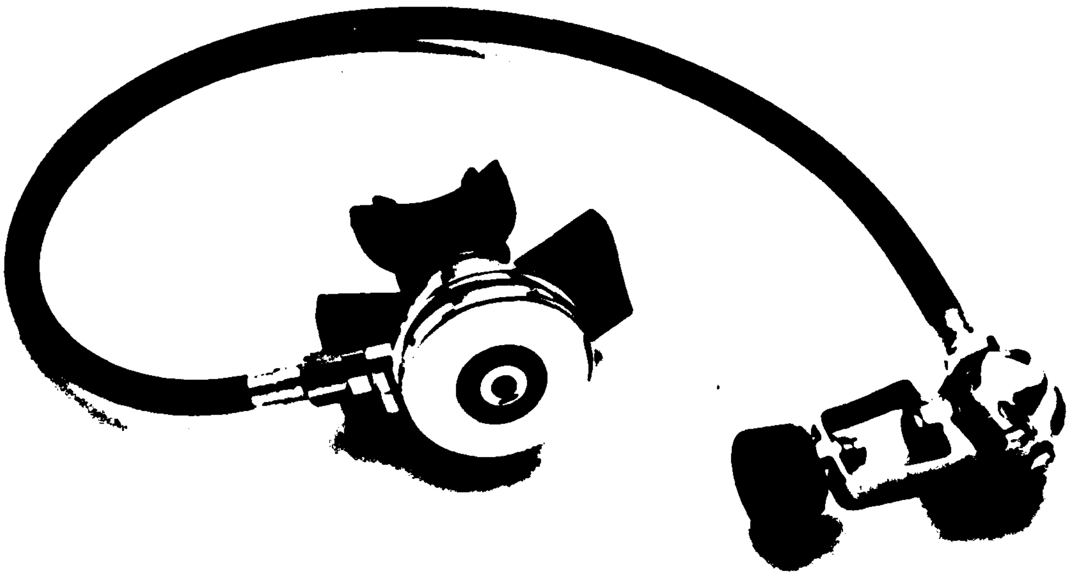
A. Regulators (Continued)



Swimaster R14 Polaris Regulator

The R14 regulator is designed for simplicity and reliability. The piston operated first stage is coupled with a chrome-plated brass, venturi-assisted second stage. Parts are provided in the first stage body for a submersible pressure gauge and a buoyancy compensator inflator or octopus set up.

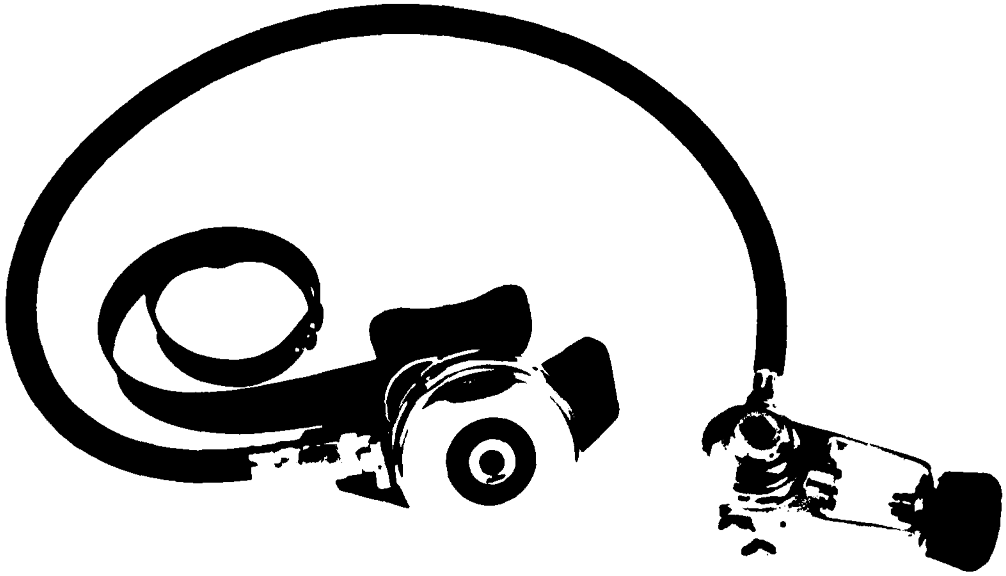
A. Regulators (Continued)



Swimaster MR12

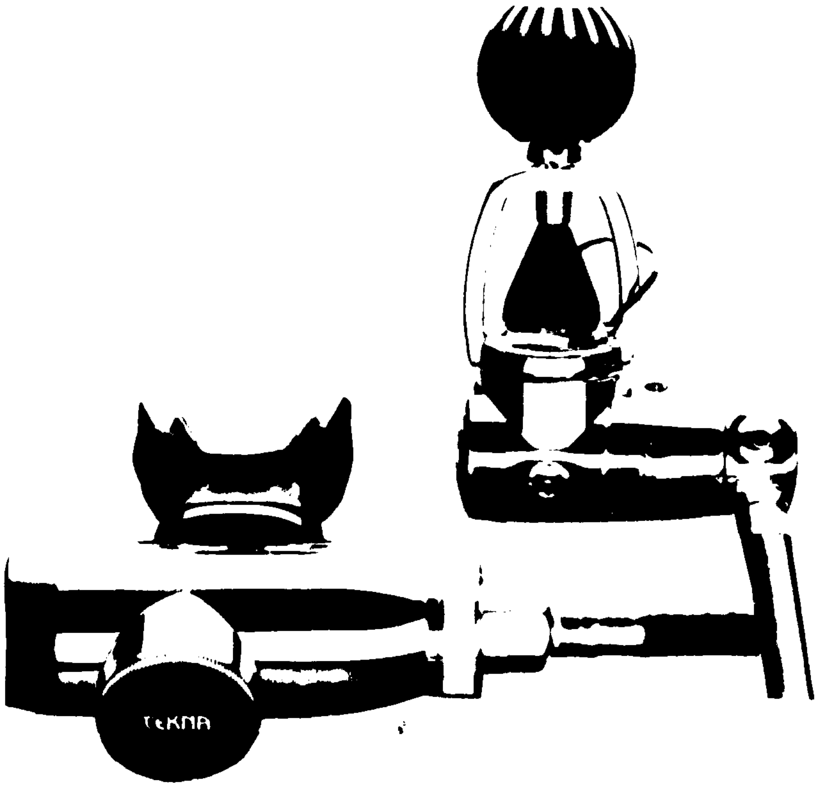
The Swimaster MR12 is a fully balanced diaphragm first stage with adjustable intermediate pressure. It has one high pressure port and two extra low pressure ports for an additional second stage and a buoyancy compensator inflator. The placement of venturi jets in the chrome plated brass second stage is designed for low breathing resistance.

A. Regulators (Continued)



Swimaster MR12-II

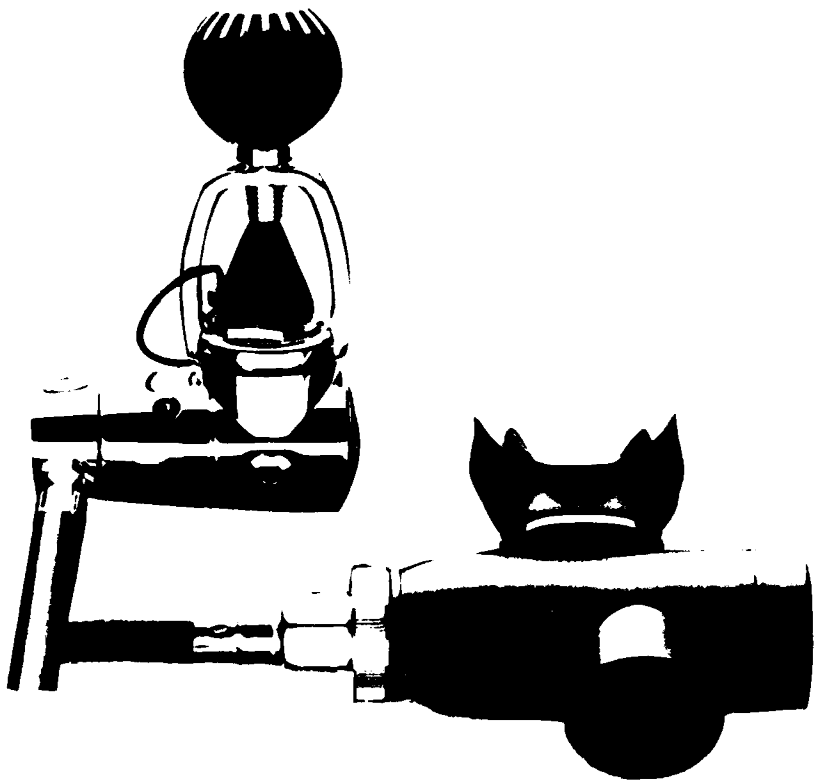
The MR12-II regulator was designed to provide superior breathing characteristics. This model combines the performance and reliability of the MR12 first stage with a new improvement for the second stage. The patented by-pass tube design creates a "vortex assist" in the second stage mouthpiece to reduce inhalation resistance at the higher flow rates.



Tekna T-2100

The Tekna T-2100 has a balanced piston first stage with two high pressure ports and four low pressure ports for versatile positioning on the tank.

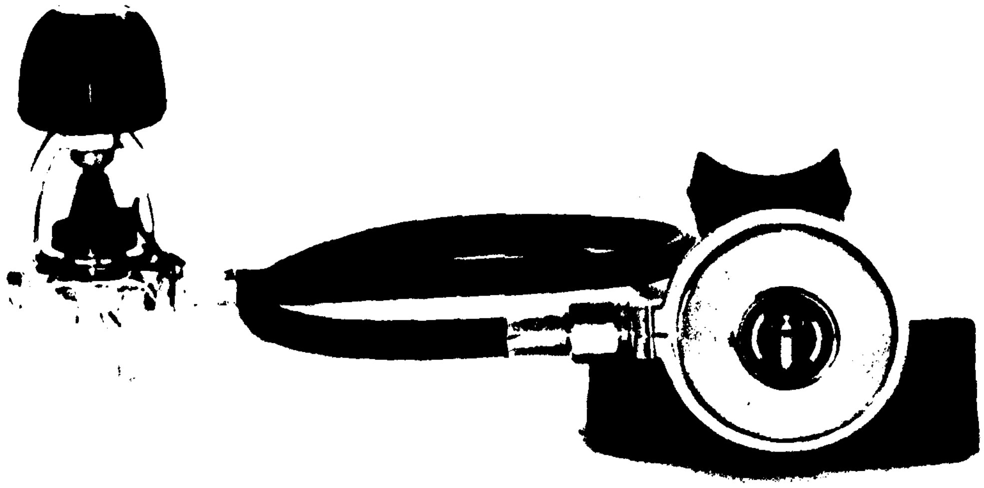
The second stage is a 9 ounce chrome plated brass, self-tuning assembly designed for ease of maintenance, and features a large silicone side exhaust valve. Inhalation effort and volume of air delivered is almost constant regardless of depth, tank pressure or breathing rate. Exhalation does not change with diver position.



Tekna T-2100B

The first stage is the same as that used with T-2100. The second stage is a 6 ounce self-tuning unit made of structural resin, with a tubular aspirator baffle in the side exhaust. The valve module, inhalation diaphragm and exhaust valve are the same as that used in the T-2100.

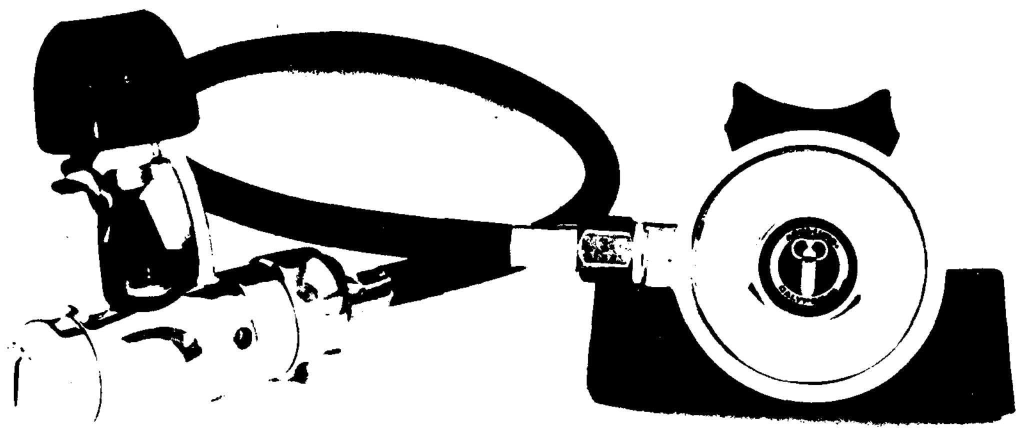
A. Regulators (Continued)



U. S. Divers Aquarius

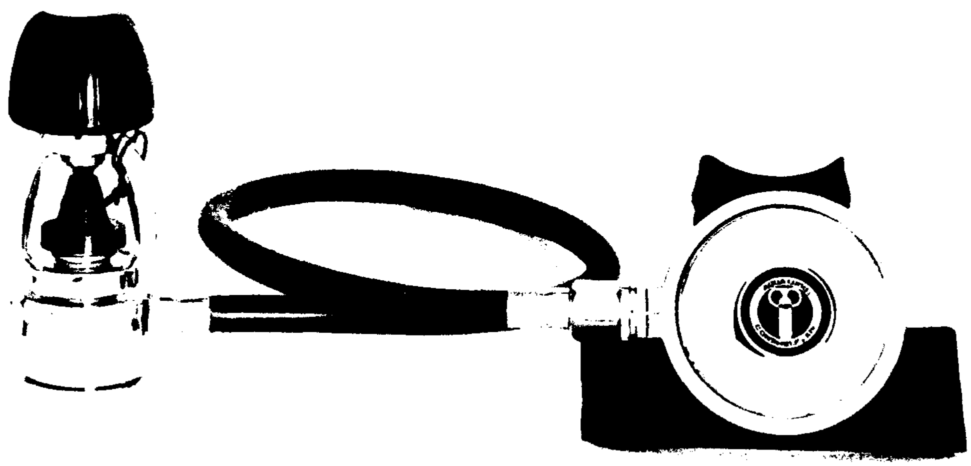
The Aquarius is a high performance regulator with the same patented, venturi assisted second stage as the other U. S. Divers regulators. The second stage also features oversized exhaust tube and Teflon tipped diaphragm lever. It features two low pressure ports and one high pressure port, and adjustable intermediate pressure. The first stage has only one moving part in its single piece forged body and yoke.

A. Regulators (Continued)



U. S. Divers Calypso VI

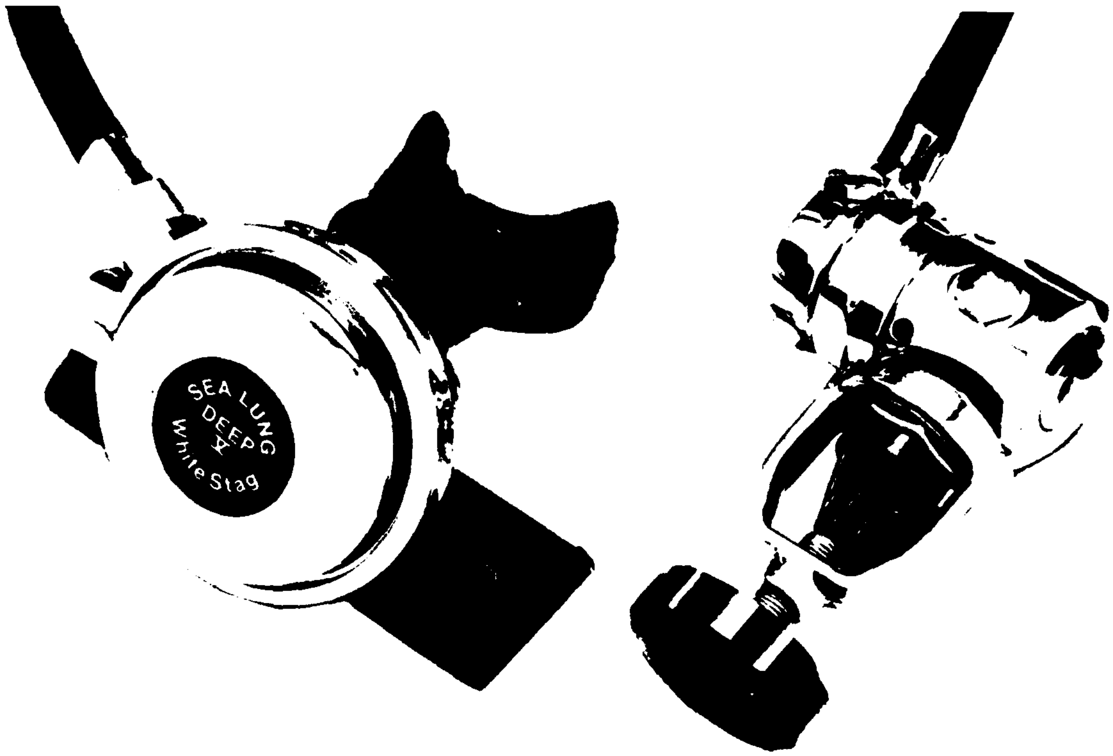
The Calypso first stage is balanced with a reversible high-pressure seat and stainless steel piston. Two low pressure ports allow the use of L.P. inflator plus octopus or pneumatic tools. These ports are on a special 360 degree swivel connection while the high pressure port comes off at 45 degrees to avoid hose kinking. The body is a forged one-piece design. The second stage is the same as the Aquarius.



U. S. Divers Conshelf XIV

The Conshelf XIV features a balanced diaphragm design allowing increased flow capability and decreased breathing effort. A swivel yoke design allows 360 degree adjustment of the first stage. Two additional low pressure ports are provided for L.P. attachments and a high pressure port for submersible pressure gauges. The regulator has few moving parts for low maintenance. The second stage is the same as the Aquarius.

A. Regulators (Continued)



White Stag Deep V

The Deep V first stage is designed to fit all domestic tank and valve combinations, and features a fully balanced stainless steel flow-through piston. The 360 degree low pressure swivel cap has three low pressure ports, and two high pressure ports.

The second stage features an adjustable orifice to allow maximum fine tuning. The exhaust valve and diaphragm are made of silicone for stabilizing performance in various water temperatures. The housing is of Lexan and the total unit weight is only 6 ounces.

B. Test Results

Due to the enormous volume of data involved in this report, a detailed analysis of the results of each test is not feasible. However, the following is a detailed discussion of the three areas evaluated; breathing resistance, breathing work and first stage performance.

The results of each test are listed in alphabetical order by manufacturer in Appendix C. (See Table of Contents). NOTE: Some figures do not have complete data at all depths and RMV's because tests were terminated at the maximum depth and RMV indicated due to excessive breathing resistance.

C. Breathing Resistance Tests

Regulator breathing resistance is a measure of the exhalation and inhalation effort required by the diver. As seen in Figure 3, a pressure transducer is located in the oral cavity of the second stage mouthpiece. This transducer is used to measure the positive pressures generated during exhalation and the negative pressures produced during inhalation. The signal from the transducer is fed into the y-axis of an x-y plotter to measure inhalation and exhalation effort. The signal to the x-axis of the x-y plotter comes from a position transducer mounted on the breathing machine which indicates tidal volume. The combination of signals to the x-y plotter generates the graph illustrated in Figure 4, called a P-V loop. From the P-V loop at a given RMV and depth, the breathing resistance of the regulator is determined. The peak exhalation and inhalation pressures are measured from the zero pressure reference line. The cracking pressure spike, which is the effort required to initially start flow upon inspiration, at times may represent the peak inhalation pressure but is normally ignored because it represents very little breathing work. As evident from the P-V loop, maximum breathing resistance normally occurs in scuba regulators at the point of peak flow or, in other words, halfway through the inhalation or exhalation cycle. The phase relationship between breathing resistance and tidal volume is better illustrated in Figure 5 where the two components of the P-V loop are broken down into individual graphs. The breathing resistances plotted for each regulator represent the maximum pressures measured, except for cracking pressure, during one complete breath at a specified depth and RMV. Air supply pressure to the first stage was 1000 psig at all depths except 0, 99, and 198 fsw where inhalation resistances were also measured at 500 and 300 psig. These low supply pressure tests are noted as separate data points on the breathing resistance graphs for each regulator. At a moderate work rate of 40 RMV none of the regulators tested showed a significant decrease in performance by reducing first stage supply pressure to 500 psig at depths down to 99 fsw. At deeper depths, higher RMV's and 300 psig supply pressure, some degree of performance loss is expected and the extent is strictly a function of first stage design. It is important to understand that inhalation effort is affected by the design of both the first and second stage pressure reducing valves. Exhalation effort, however, is simply a function of the size of the exhaust flow passages and the stiffness of the rubber exhaust mushroom valve, i.e. the softer the mushroom valve and the larger the flow passage, the less the exhalation effort.

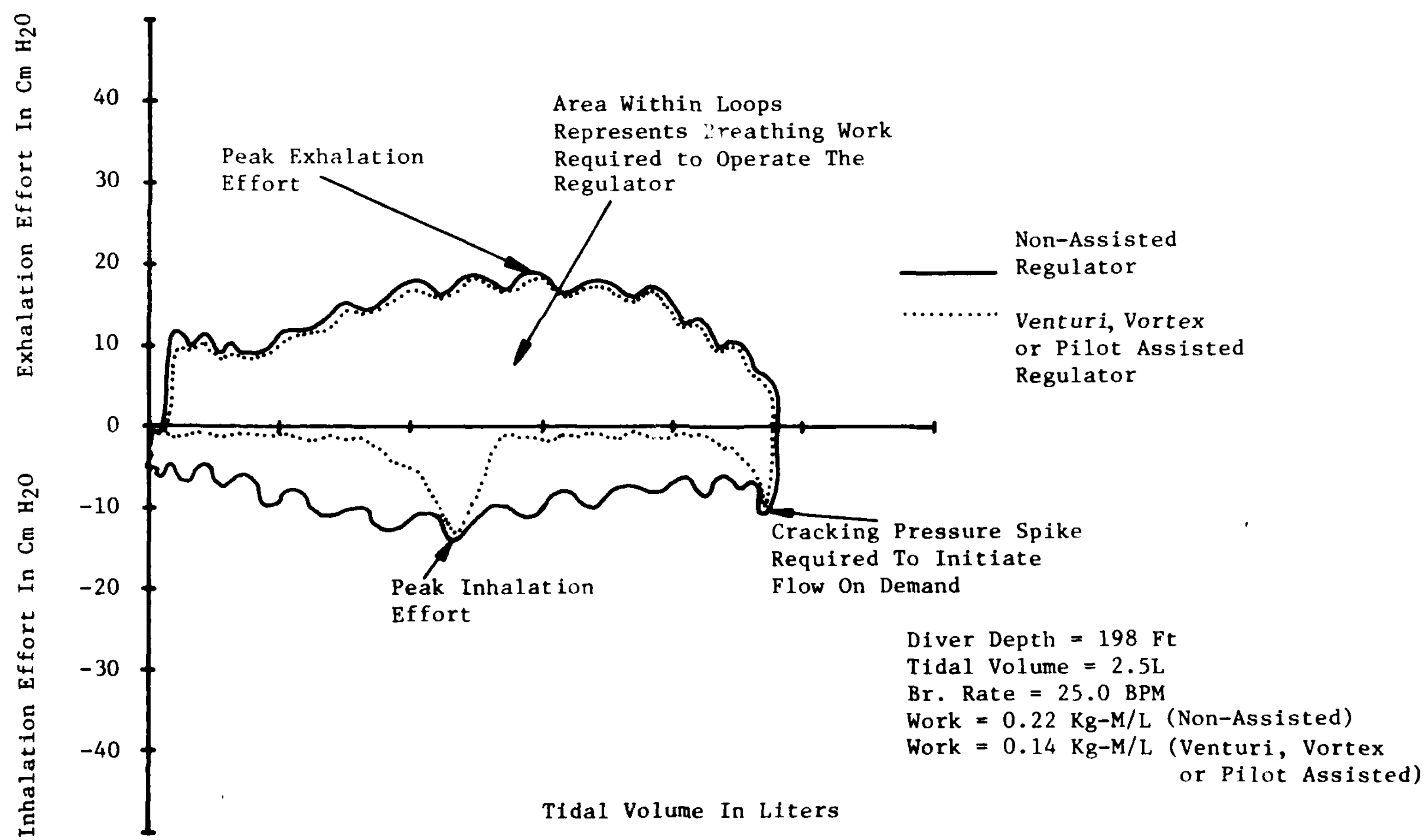


Figure 4. Sample Breathing Resistance Versus Tidal Volume Loop (P-V Loop)

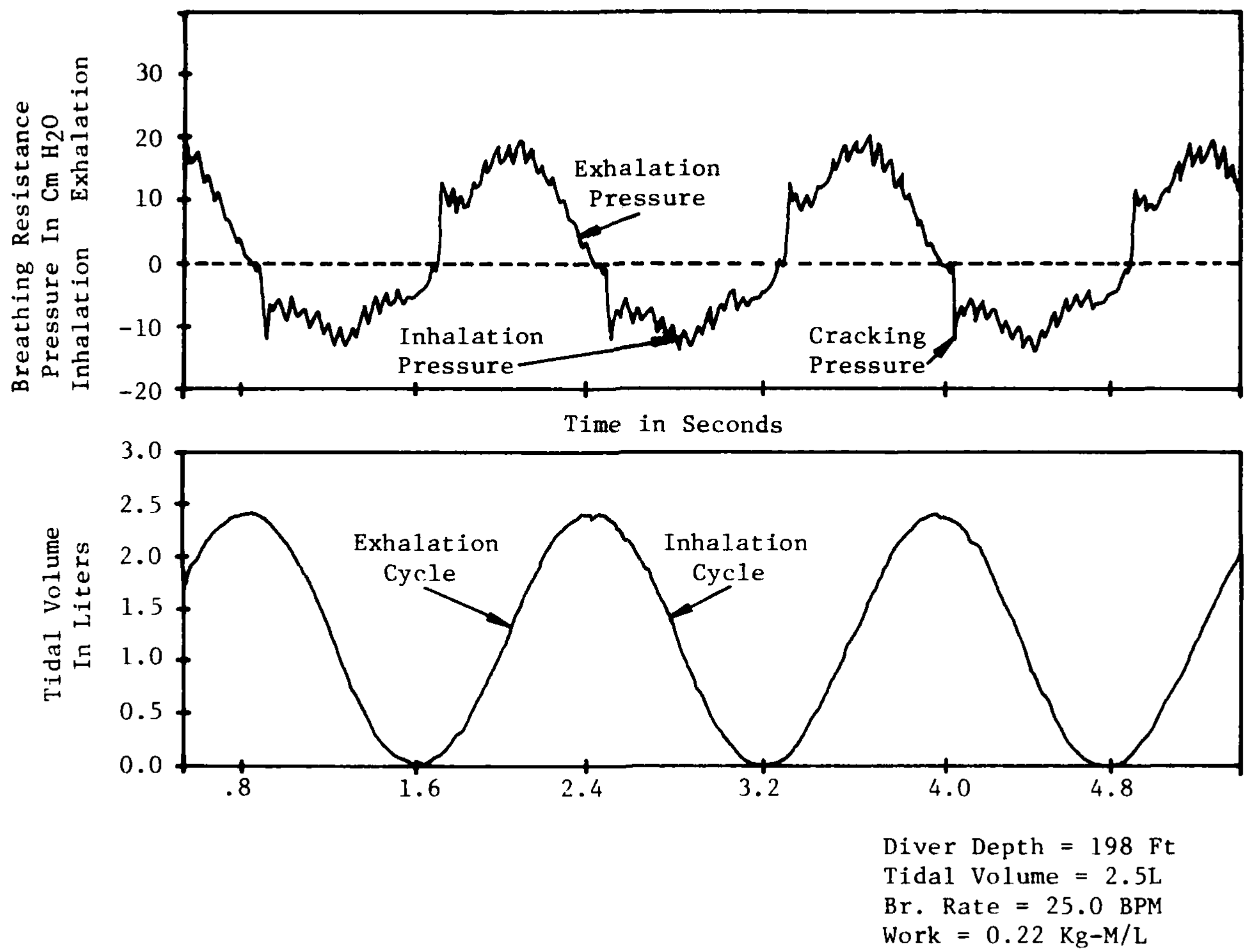


Figure 5. Sample Breathing Cycle Data

C. Breathing Resistance Tests (Continued)

A rule of thumb for analyzing breathing resistance data is as follows. It is based on the regulator performance groupings cited in the Conclusion and Recommendations section (page 49):

1. At 132 fsw and 40 RMV a regulator which exhibits low breathing effort has exhalation and inhalation values of less than 10 cm H_2O pressure each.

2. At 132 fsw and 40 RMV a regulator which exhibits moderate breathing effort has exhalation and inhalation values of less than 15 cm H_2O pressure each.

3. At 132 fsw and 40 RMV a regulator which exhibits high breathing effort has exhalation and inhalation values in excess of 20 cm H_2O pressure each.

Breathing resistance was measured at five different RMV and depths ranging from 0 to 300 fsw. While the NEDU performance spec occurs at only one set of test parameters (62.5 RMV and 132 fsw), the other depths and RMV's are measured to give an indication as to the full range of regulator performance.

D. Breathing Work

Breathing work is defined as the external respiratory work required by a diver to operate his breathing apparatus. Since pressure multiplied by change in volume equals work by definition, the area enclosed by the pressure volume loop (Figure 4) is equal to the work of breathing required to operate the scuba regulator.

The previous NEDU performance requirement for scuba regulators was based on a mil spec which cited peak inhalation and peak exhalation pressures as the standards for evaluation (reference 1) and is illustrated in Figure 1. Breathing resistance is a reasonable method of evaluating scuba regulator performance. Because peak breathing effort normally occurs at the peak inhalation and exhalation flow rates in a conventional, non-assisted regulator, breathing resistance and breathing work are approximately proportional. Therefore, breathing resistance is a valid measure of comparing the performance of this group of regulators.

However, few scuba regulators produced today are purely non-assisted. Most have venturi, vortex or pilot assisted boosters to assist second stage inhalation performance. The result is that while the peak inhalation pressures from an assisted and non-assisted regulator may be similar, the breathing work for the assisted regulator drops significantly since this peak inhalation pressure occurs for a much shorter period of time. This fact is illustrated in Figure 4. Work of breathing, defined as the area enclosed within the P-V loop, is seen to be much larger for the non-assisted regulator (solid curve) than the area representing the assisted unit (dotted curve). Consequently while peak pressures on two different regulators may be identical, the actual respiratory work required from the diver can be significantly different. In addition, how "hard", or "easy" a regulator breathes is a

D. Breathing Work (Continued)

direct function of whether or not the diver has to maintain the peak inhalation and exhalation pressures for the entire breathing cycle.

It was for this reason that breathing work rather than breathing resistance is the more valid approach for setting performance standards.

E. First Stage Performance

The performance of the scuba regulator's first stage is critical to the inhalation effort required by the diver. The first stage must supply air at a sufficiently high pressure to the second stage in order for the regulator to function properly. The results of these tests have revealed that as inhalation effort increases with depth and work rate, it is often due to failure of the first stage to supply sufficent gas to the second stage. This is quite interesting since most design work in recent years has been directed towards lowering breathing resistance by improving second stage rather than first stage design.

The spring/valve mechanism of most second stage regulators is designed to function with minimum inhalation effort when supplied with 125 to 150 psig O/B from the first stage. This intermediate pressure out of the first stage is normally set under static or no-flow conditions by the manufacturer. Upon inhalation this pressure drops as the air flows from the first to the second stage. As a diver decends and increases his work rate, the increased flow from the first to the second stage causes the pressure drop from the static setting to increase dramatically. Consequently, the second stage may no longer be receiving air at a pressure and volume sufficiently high to effectively meet the diver's inhalation demands, resulting in increased inhalation effort. This phenomena increases when the supply pressure to the first stage is below 500 psig, further reducing regulator efficiency.

The maximum intermediate pressure drop from the static setting was measured as seen in Figure 3 by placing a pressure transducer in the hose between the first and second stages. By plotting the intermediate pressure drop from the static setting versus depth at each RMV tested, the design limitations of every first stage can be evaluated. Correlating this information with the breathing resistance graphs, poor regulator performance can be traced to the first stage, second stage or both.

For example, a regulator with a static intermediate pressure of 140 psig O/B can usually operate efficiently with dynamic pressures as low as 115 psig O/B. Pressure losses greater than this during inhalation generally result in significantly increased inhalation effort and breathing work. When pressure losses approach 40 to 50 psig less than static, the regulator ceases to function in a manner which can effectively support a diver. Conversely, when a regulator exhibits poor inhalation performance with very small intermediate pressure drops, the problem usually exists in the second stage design.

In analyzing the data presented, it is a simple matter to determine

E. First Stage Performance (Continued)

which first stages exhibit the least intermediate pressure loss at the deeper depths and higher work rates in order to determine the best design. Correlating this information with the breathing resistance graphs for a given regulator enables the reader to trace poor regulator performance to the first stage, second stage or both.

Note: First Stage Performance is plotted for all regulators except the Dacor C3NB two hose model which had no provision for attaching a transducer to measure this parameter.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The overall performance of the regulators tested was found to be outstanding. All but 5 of the regulators tested met the performance requirements of Mil-R-24169A. This is a significant improvement over regulator performance of only four years ago. It is important to understand that while only seven regulators met the upgraded 1980 NEDU performance requirement, regulators which meet the past requirement of Mil-R-24169A are considered to be safe and effective. The 1980 NEDU performance requirement is specifically designed to provide the working Navy diver with the highest performance equipment available. If a specific model does not meet this new requirement, the regulator is not considered substandard provided it meets the requirements set forth in Mil-R-24169A.

The regulators are divided into three groups as follows:

Group A. Regulators which met or exceeded the upgraded NEDU performance requirement of 0.14 kg·m/l at 62.5 RMV and 132 fsw (See Figure 2).

Group B. Regulators which met or exceeded the past NEDU performance requirement based on Mil-R-24169A (See Figure 1).

Group C. Regulators which did not meet the past NEDU performance requirement based on Mil-R-24169A.

Note: The regulators in each group are listed in alphabetical order.

Group A

1. Poseidon Cyclon 300
2. Scubamaster Model 7687
3. Scubapro Air I/Mk V (4-Port Swivel)
4. Scubapro Air I/Mk V (5-Port Swivel)
5. Tekna T-2100B
6. U. S. Divers Calypso VI
7. U. S. Divers Conshelf XIV

Group B

1. AGA Divator 324/U.S.D Conshelf XIV

A. Conclusions (Continued)

2. Dacor Pacer 150
3. Dacor Pacer 300
4. Dacor Pacer 600
5. Dacor Pacer 900
6. Jepsen Model 200
7. Scubapro Mk V (4-Port Swivel)
8. Scubapro Mk V (5-Port Swivel)
9. Scubapro Pilot Mk V (4-Port Swivel)
10. Sherwood Selpac Model 2000
11. Sherwood Selpac Model 3100
12. Sherwood Selpac Model 4100
13. Sportsways Model WL-200
14. Sportsways Model W-600
15. Sportsways Model W-900
16. Sub Aquatic Systems Model Sub II
17. Sub Aquatic Systems Model Sub X
18. Swimaster R14 Polaris
19. Swimaster MR12
20. Swimaster MR12-II
21. Tekna T-2100
22. U. S. Divers Aquarius
23. White Stag Deep V

Group C

1. Dacor Model C3NB (Two Hose Regulator)
2. Seapro FSDS-10
3. Seapro FSDS-50
4. Sportsways 1390
5. Sportsways W-950 Arctic

*6. Scubapro Air II/Mk V (4-Port Swivel) *(a buoyancy compensator inflator with integral second stage - not a diver's primary regulator)

B. Recommendations

It is recommended that the U. S. Navy amend its guidance to fleet divers to appropriately reflect the results of this exhaustive study. For the deeper, more demanding dive scenarios, use of regulators from Group A is clearly preferred.

REFERENCES

1. Department of the Navy Military Specification MIL-R-24169A, Regulator, Air, Demand, Single Hose, Nonmagnetic, Divers, 22 March 1967.

APPENDIX A

TEST PLAN

1. a. Insure that regulator is set to factory specifications and is working properly.

   b. Chamber on surface.

   c. Calibrate transducers.

   d. Open air supply valve to test regulator and set supply pressure to 1000 psig.

   e. Adjust breathing machine to 1.5 liters tidal volume and 15 BPM and take data.

   f. Adjust breathing machine to 2.0 liters tidal volume and 20 BPM and take data.

   g. Adjust breathing machine to 2.5 liters tidal volume and 25 BPM and take data.

   h. Adjust breathing machine to 2.5 liters tidal volume and 30 BPM and take data.

   i. Adjust breathing machine to 3.0 liters tidal volume and 30 BPM and take data.

   j. Adjust air supply pressure to 500 psig and repeat steps 1e-1i.

   k. Adjust air supply pressure to 300 psig and repeat steps 1e-1i.

2. a. Pressurize chamber to 66 fsw in 33 fsw increments and repeat steps 1d-1i at each stop.

   b. Pressurize chamber to 99 fsw and repeat steps 1d-1k.

   c. Pressurize chamber to 165 fsw in 33 fsw increments and repeat steps 1d-1i at each stop.

   d. Pressurize chamber to 198 fsw and repeat steps 1d-1k.

   e. Pressurize chamber to 300 fsw and repeat steps 1d-1i.

APPENDIX B

TEST EQUIPMENT

(Note: Equipment corresponds to that in Figure 3).

1. MFE Model 715M X-Y plotter
2. Validyne CD-23 transducer readout
3. NEDU breathing simulator
4. Waters Model LF-12-0A-101 piston position transducer
5. Gould Brush Model 2600 chart recorder
6. Validyne Model DP-15 pressure transducer w/200 psid diaphragm
7. 71.2 cubic foot scuba tank
8. Tescom Model 44-1316-2122 pressure regulator
9. Roylyn 0-1500 psig air supply pressure gauge (Model No. 25545-31B14)
10. Wet test box
11. Standard scuba tank valve
12. Bubble dampening mat
13. NEDU EDF chamber complex
14. Mensor Model 2792 depth gauge
15. Test regulator (first and second stage)
16. Validyne Model DP-15 pressure transducer w/1.00 psig diaphragm

APPENDIX C
GRAPHS

Index of Graphs

Figure Series - Graph Number

Figure Series - 1 -------- Breathing Resistance vs. Depth at 22.5 RMV

Figure Series - 2 -------- Breathing Resistance vs. Depth at 40 RMV

Figure Series - 3 -------- Breathing Resistance vs. Depth at 62.5 RMV

Figure Series - 4 -------- Breathing Resistance vs. Depth at 75 RMV

Figure Series - 5 -------- Breathing Resistance vs. Depth at 90 RMV

Figure Series - 6 -------- Breathing Work vs. Depth at 1000 psig Supply Pressure

Figure Series - 7 -------- First Stage Pressure Drop vs. Depth at 22.5 RMV

Figure Series - 8 -------- First Stage Pressure Drop vs. Depth at 40 RMV

Figure Series - 9 -------- First Stage Pressure Drop vs. Depth at 62.5 RMV

Figure Series - 10 ------- First Stage Pressure Drop vs. Depth at 75 RMV

Figure Series - 11 ------- First Stage Pressure Drop vs. Depth at 90 RMV

The Index of Graphs on this page, and the List of Graphs on the following page must be used together to determine the figure number for a particular graph. The figure number consists of a figure series number followed by the number of the graph (1-11). Each manufacturer has a number, and each regulator model has a letter designation.

For example, to find the figure number for Breathing Work of the Seapro FSDS-50 regulator, first find the figure series of that regulator, which in this case is 7B. Then go to the Index of Graphs and find the graph number for Breathing Work, which is 6. The figure number for the graph is 7B-6.

Note: 1. Some figures do not have complete data at all depths and RMV's because tests were terminated at the maximum depth and RMV indicated due to excessive breathing resistance.

2. Inhalation resistances are plotted as separate data points at 500 and 300 psig on the breathing resistance graphs to give an indication of regulator performance at reduced first stage supply pressures.

List of Graphs

List of Graphs (Continued)

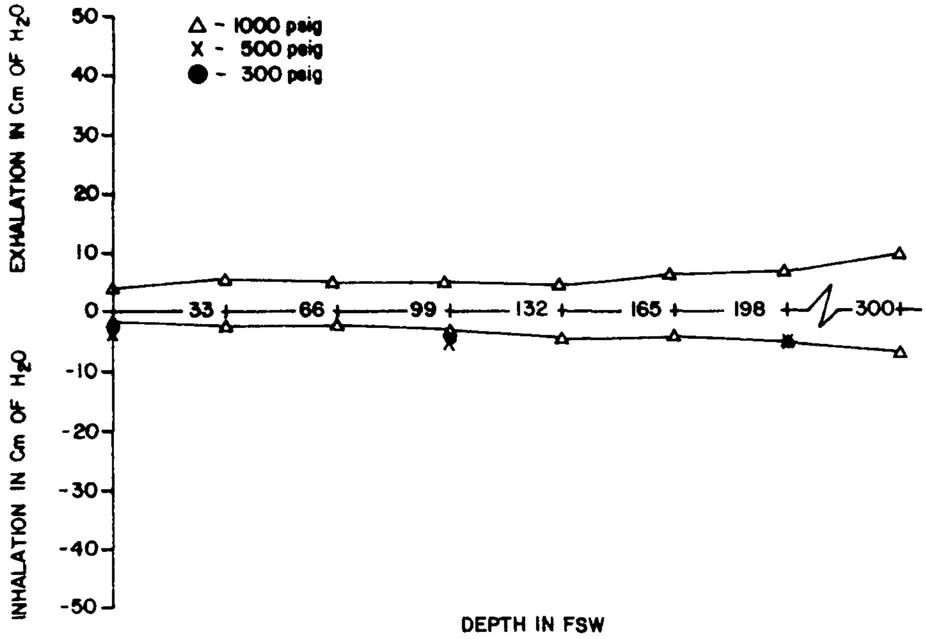


Figure 1A-1. AGA Divator 324/U.S.D Conshelf XIV
Breathing resistance vs. depth at 22.5 RMV

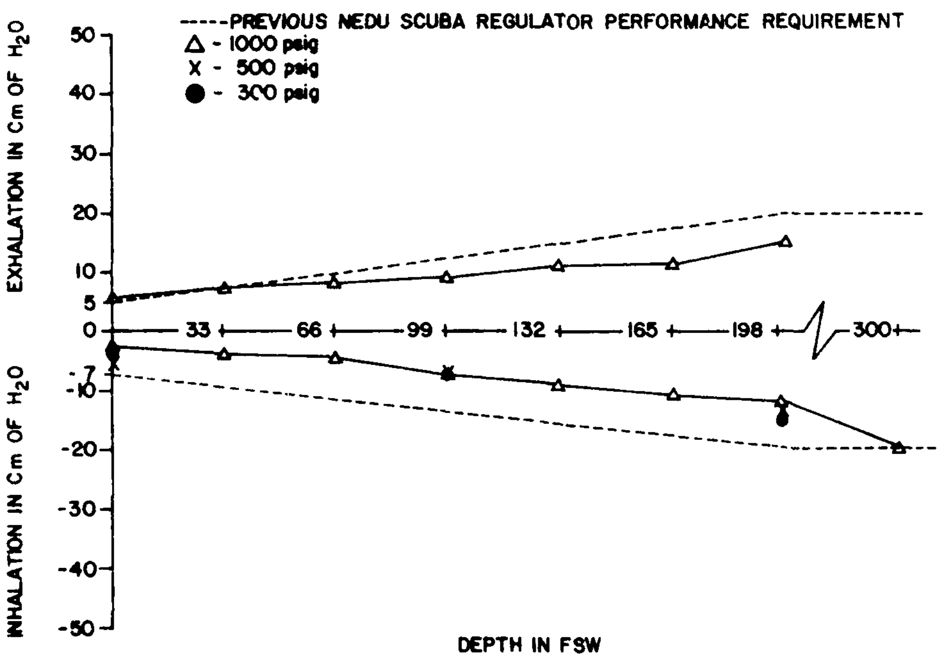


Figure 1A-2. AGA Divator 324/U.S.D. Conshelf XIV
Breathing resistance vs. depth at 40 RMV

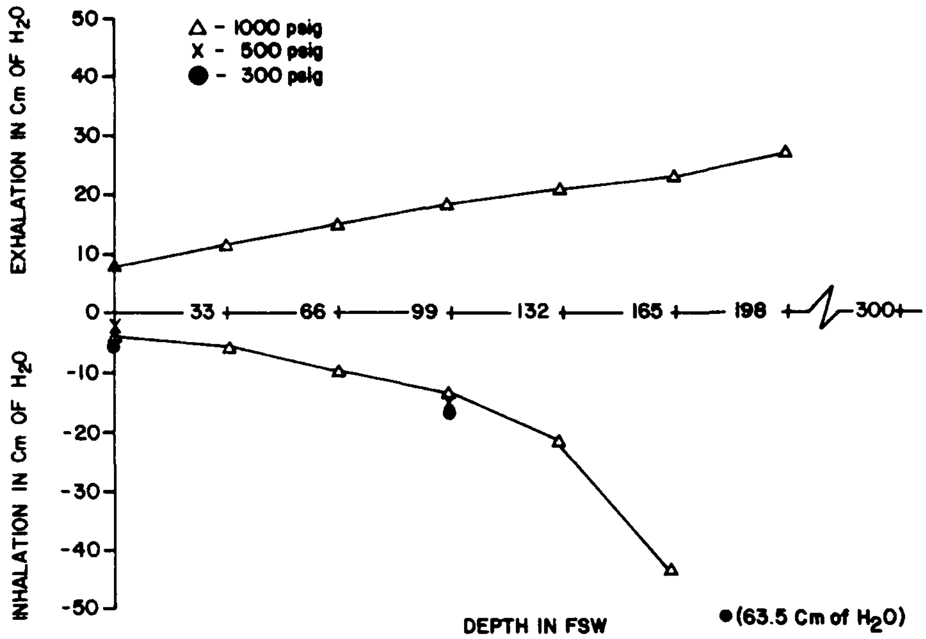


Figure 1A-3. AGA Divator 324/U.S.D. Conshelf XIV
Breathing resistance vs. depth at 62.5 RMV

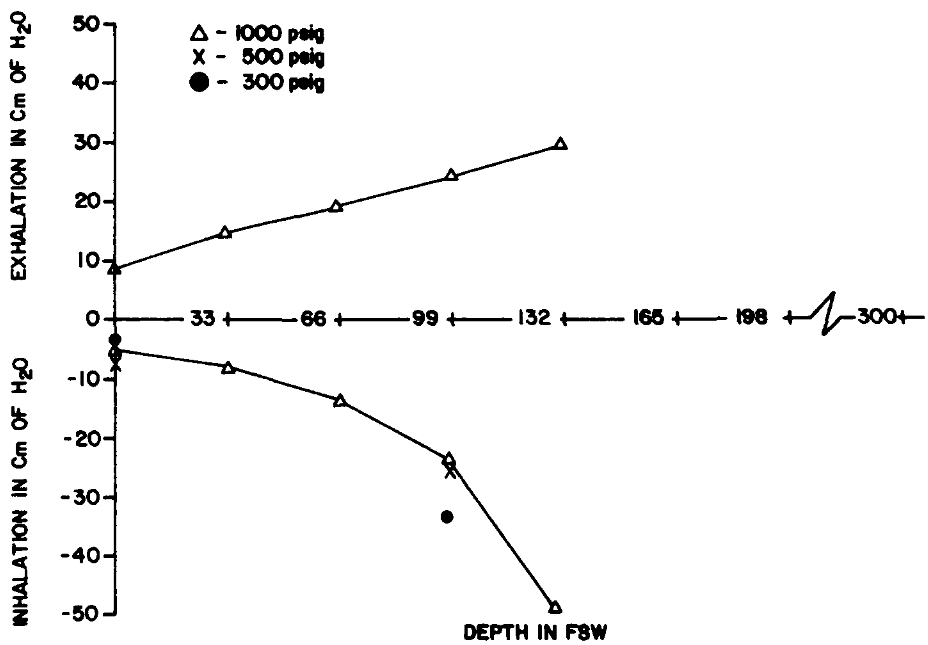


Figure 1A-4. AGA Divator 324/U.S.D. Conshelf XIV
Breathing resistance vs. depth at 75 RMV

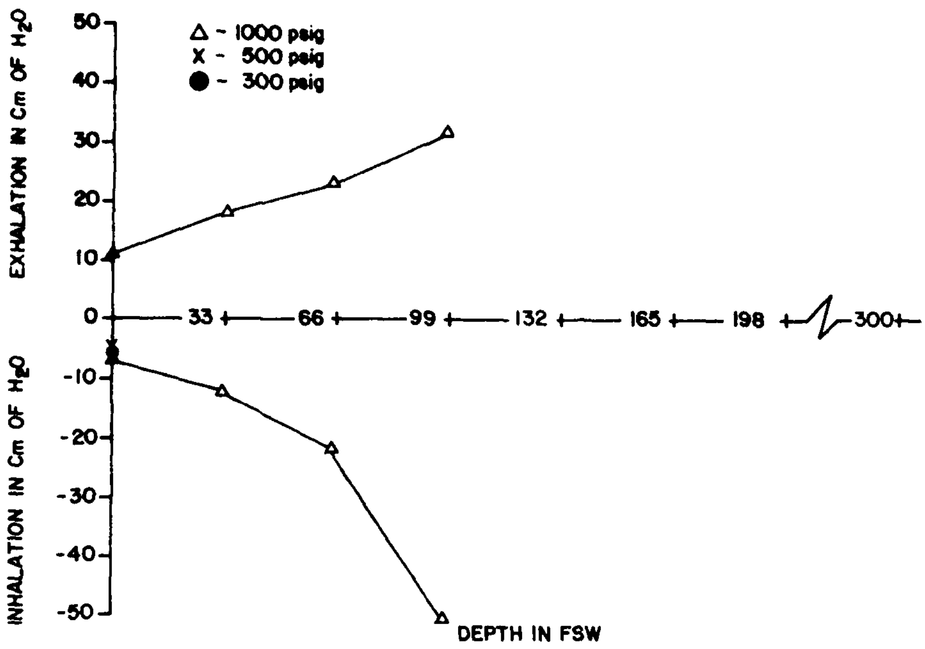


Figure 1A-5. AGA Divator 324/U.S.D. Conshelf XIV
Breathing resistance vs. depth at 90 RMV

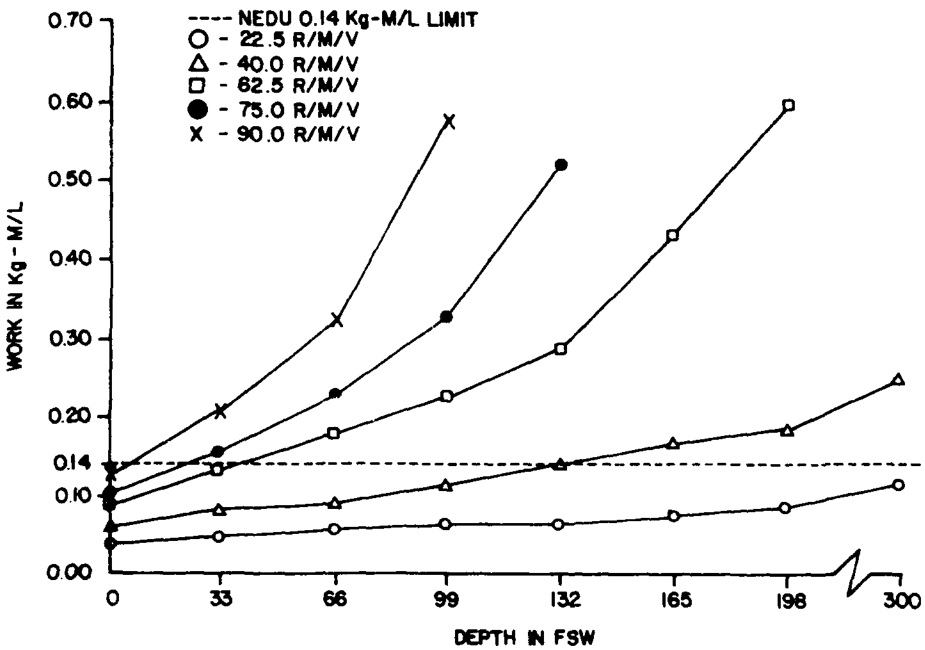


Figure 1A-6. AGA Divator 324/U.S.D. Conshelf XIV
Breathing work vs. depth at 1000 psig supply pressure

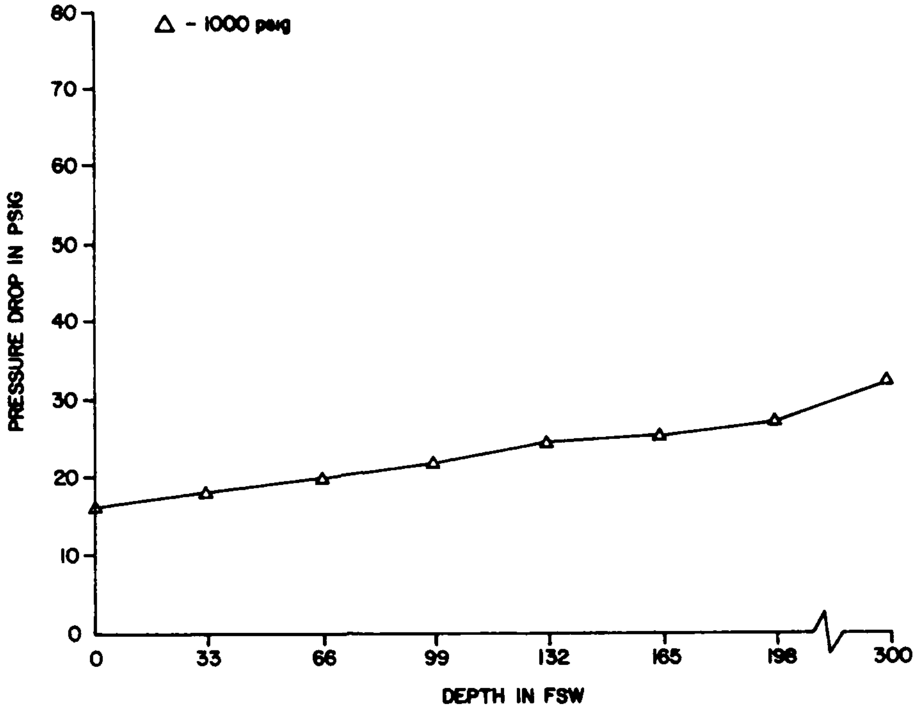


Figure 1A-7. AGA Divator 324/U.S.D. Conshelf XIV
First stage pressure drop vs. depth at 22.5 RMV

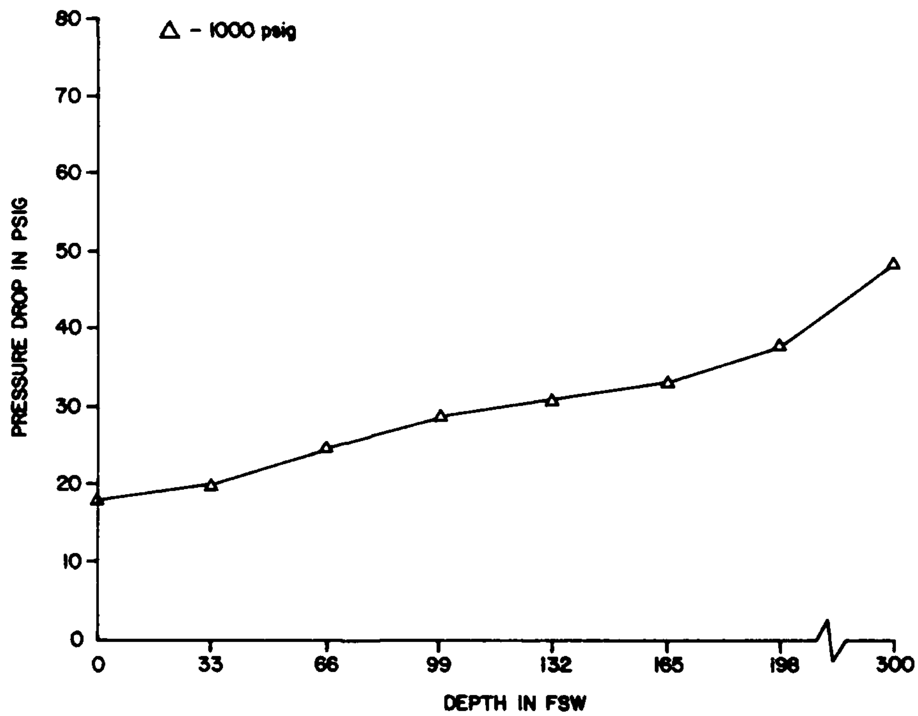


Figure 1A-8. AGA Divator 324/U.S.D. Conshelf XIV
First stage pressure drop vs. depth at 40 RMV

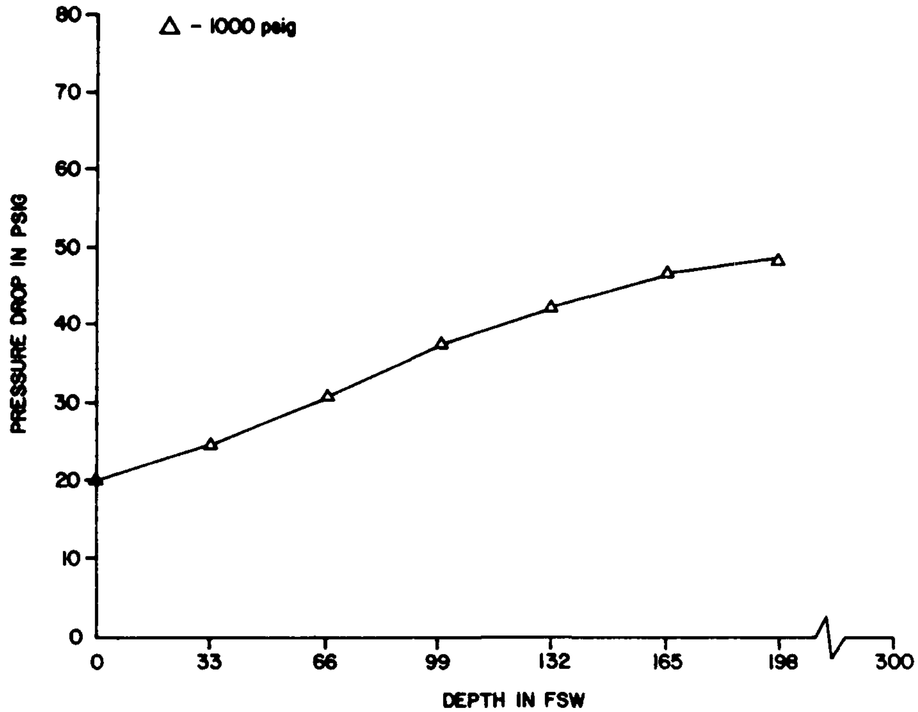


Figure 1A-9. AGA Divator 324/U.S.D. Conshelf XIV
First stage pressure drop vs. depth at 62.5 RMV

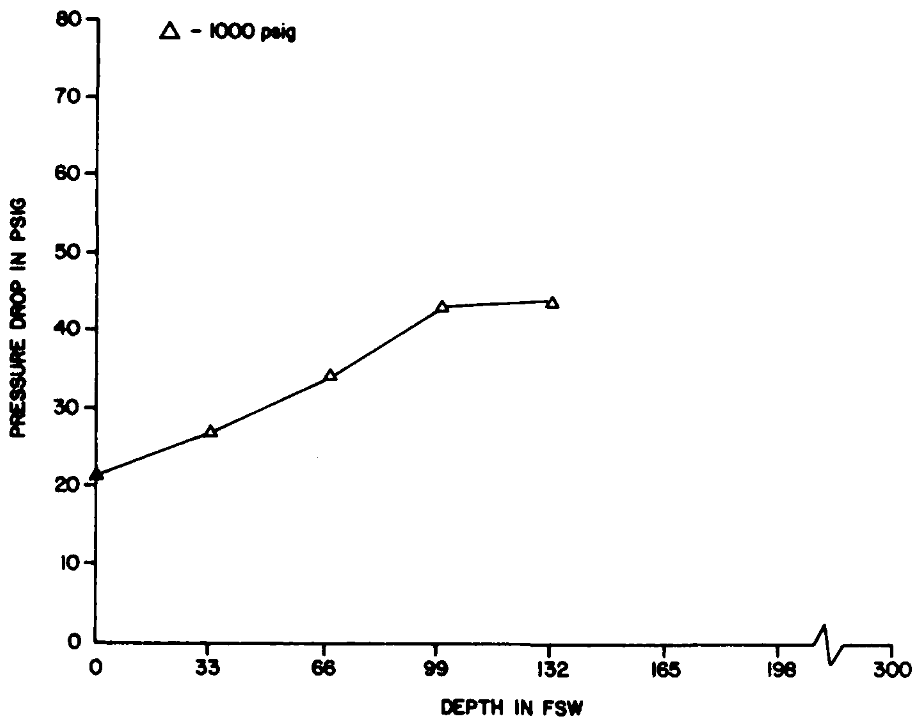


Figure 1A-10. AGA Divator 324/U.S.D. Conshelf XIV
First stage pressure drop vs. depth at 75 RMV

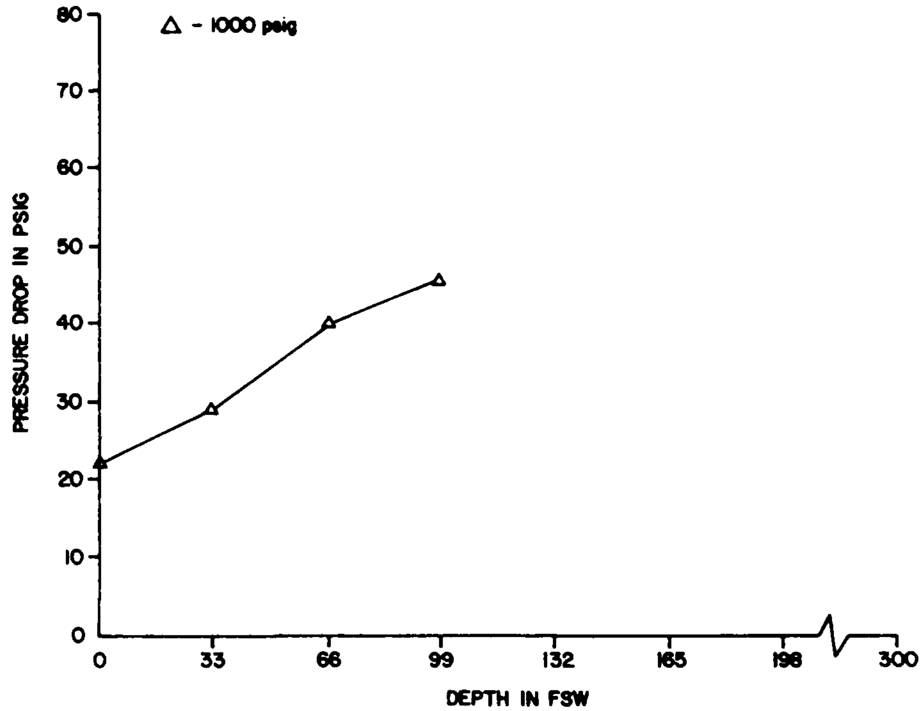


Figure 1A-11. AGA Divator 324/U.S.D. Conshelf XIV
First stage pressure drop vs. depth at 90 RMV

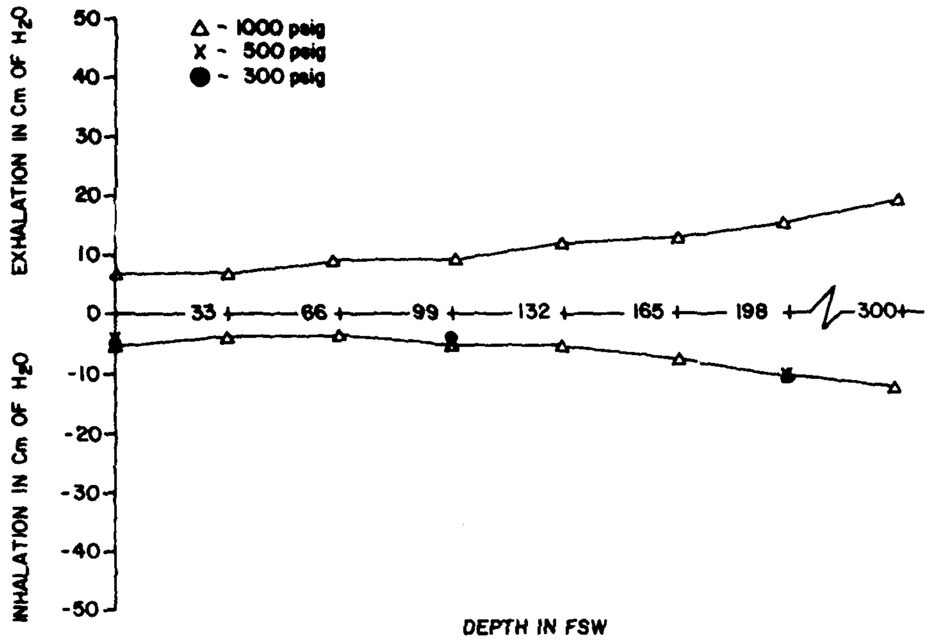


Figure 2A-1. Dacor C3NB
Breathing resistance vs. depth at 22.5 RMV

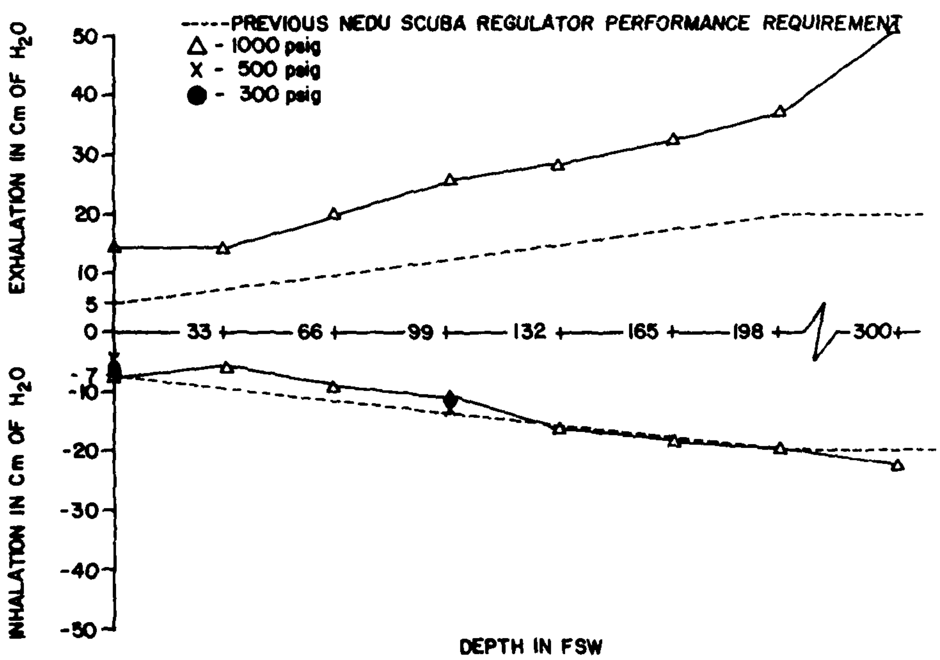


Figure 2A-2. Dacor C3NB
Breathing resistance vs. depth at 40 RMV

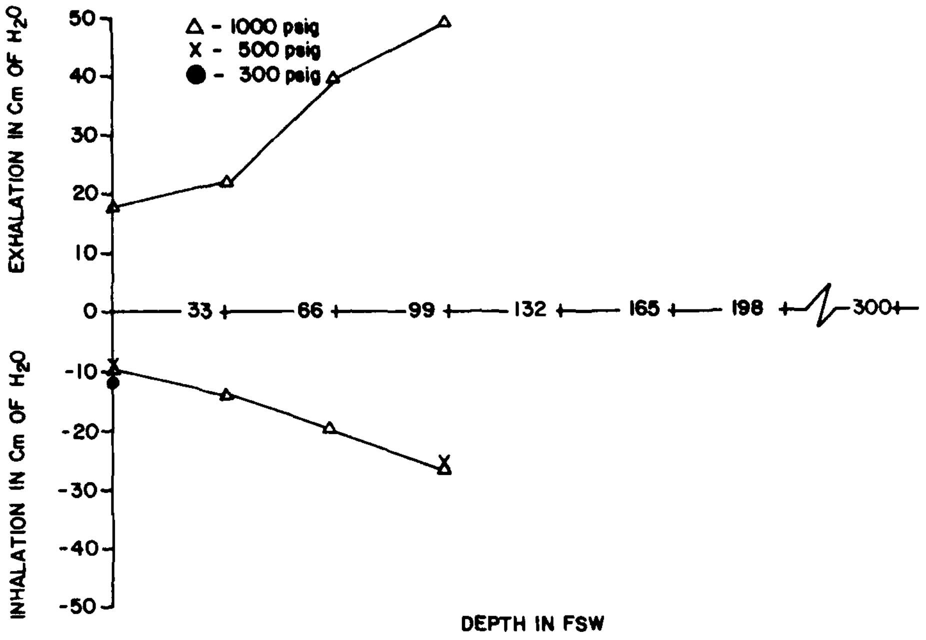


Figure 2A-3. Dacor C3NB
Breathing resistance vs. depth at 62.5 RMV

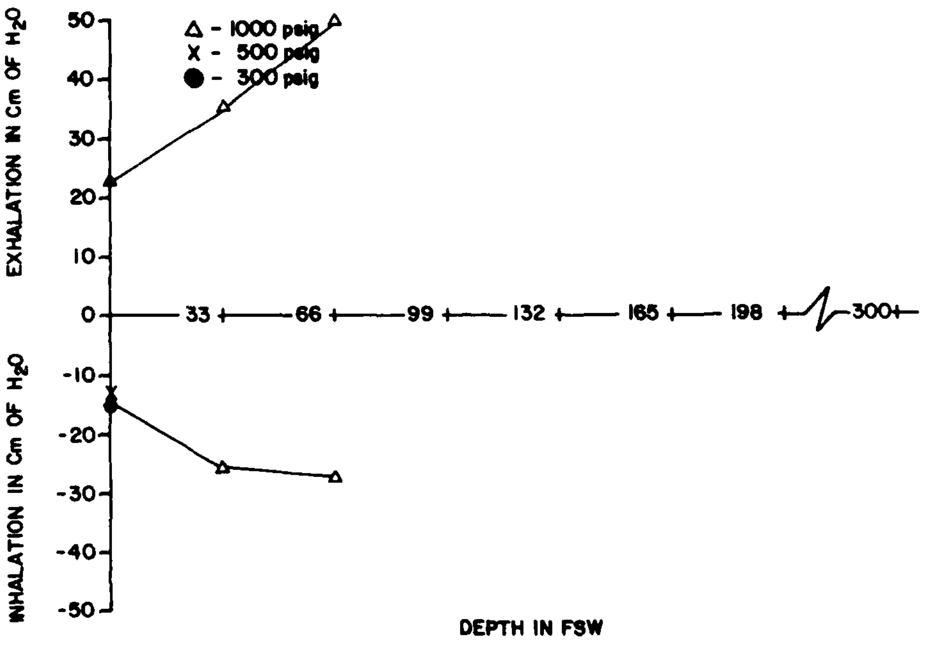


Figure 2A-4. Dacor C3NB
Breathing resistance vs. depth at 75 RMV

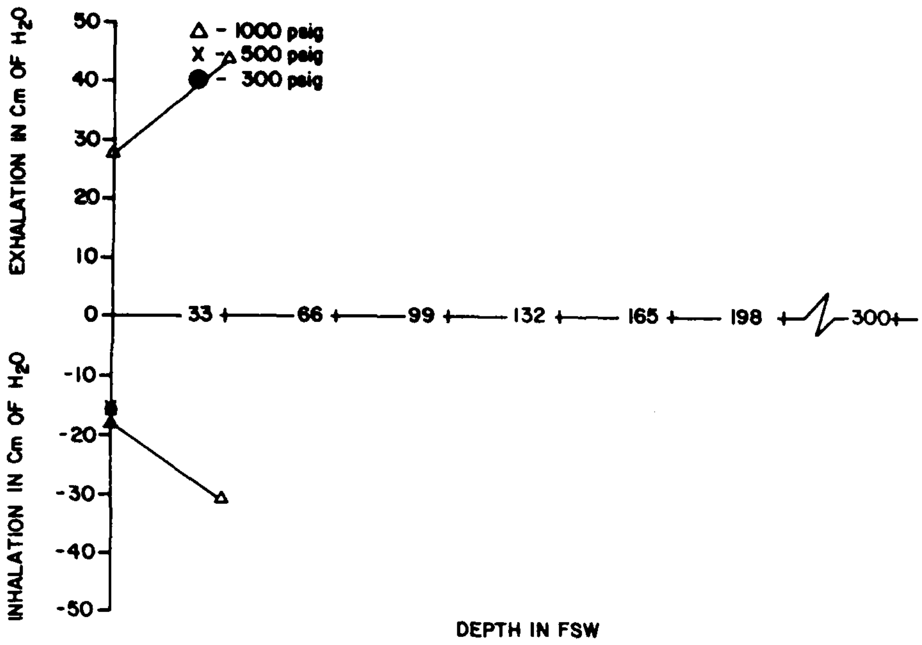


Figure 2A-5. Dacor C3NB
Breathing resistance vs. depth at 90 RMV

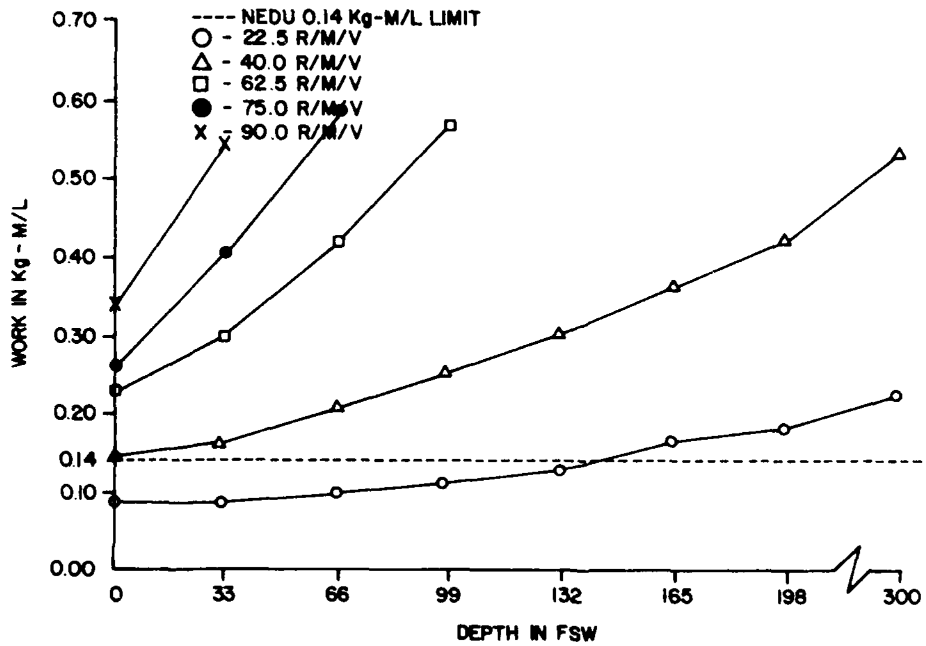


Figure 2A-6. Dacor C3NB
Breathing work vs. depth at 1000 psig supply pressure

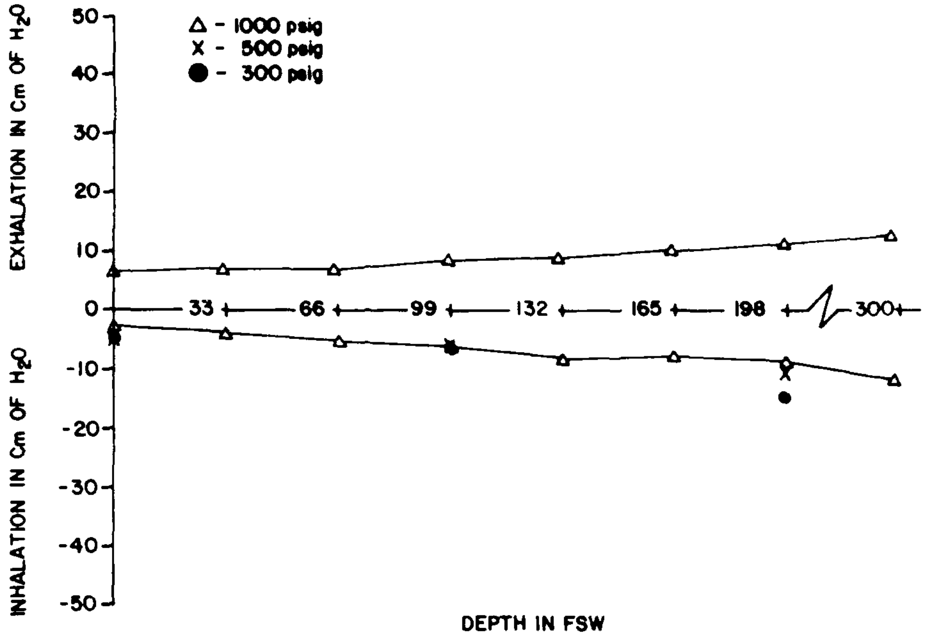


Figure 2B-1. Dacor Pacer 150
Breathing resistance vs. depth at 22.5 RMV

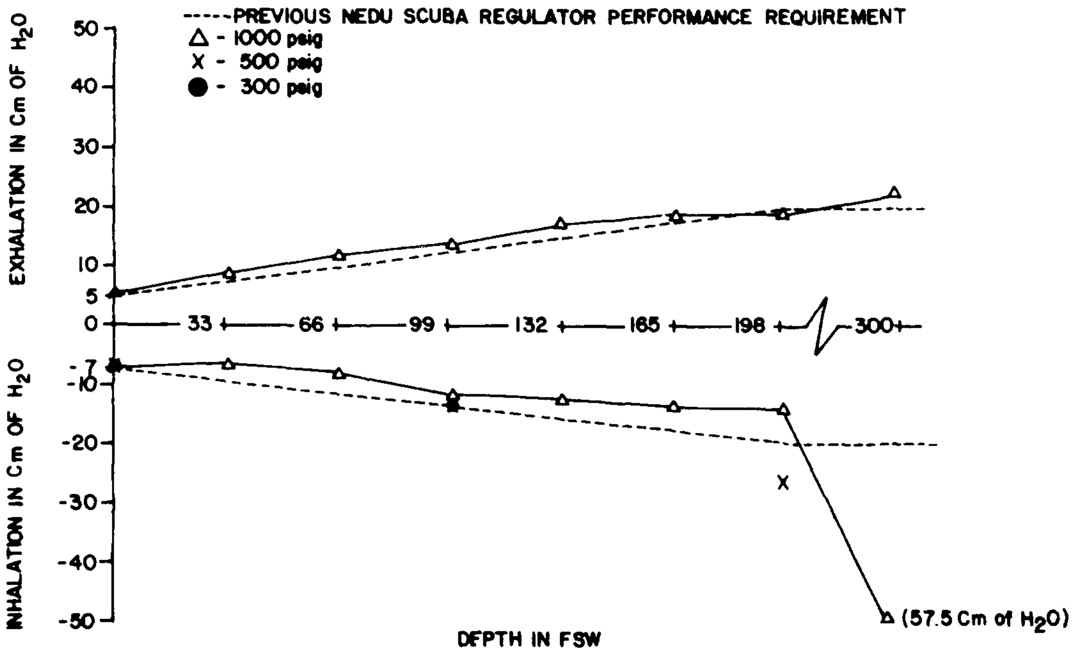


Figure 2B-2. Dacor Pacer 150
Breathing resistance vs. depth at 40 RMV

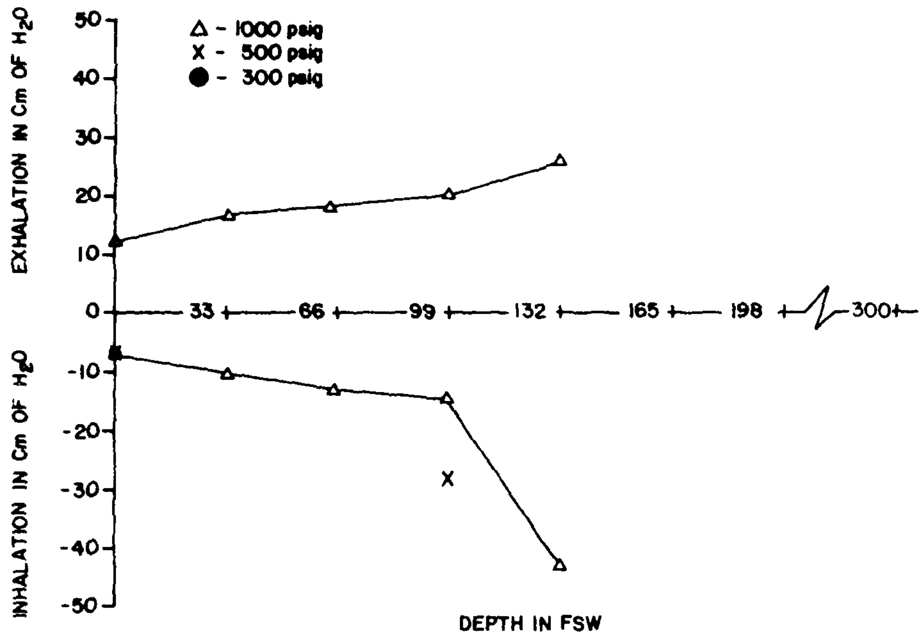


Figure 2B-3. Dacor Pacer 150
Breathing resistance vs. depth at 62.5 RMV

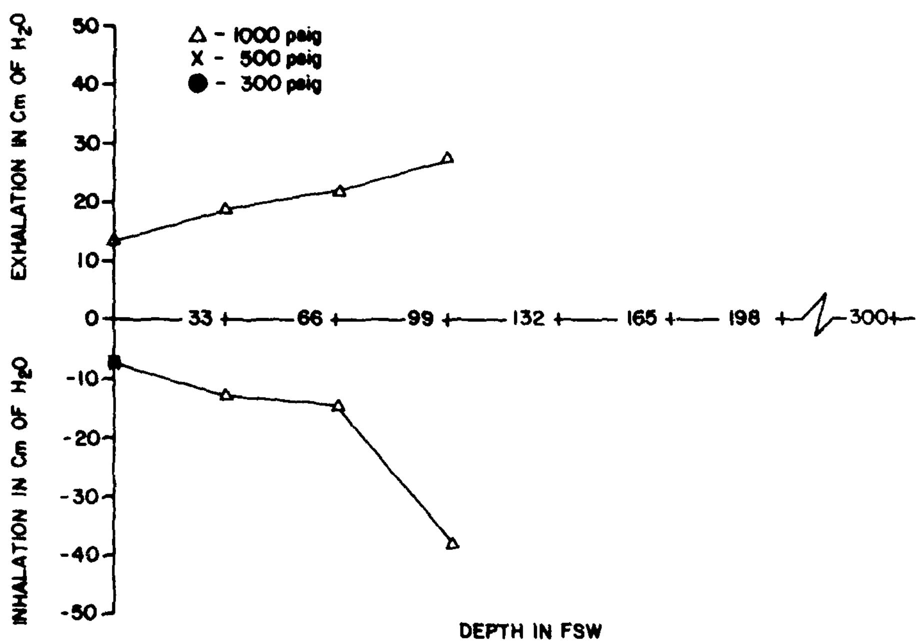


Figure 2B-4. Dacor Pacer 150
Breathing resistance vs. depth at 75 RMV

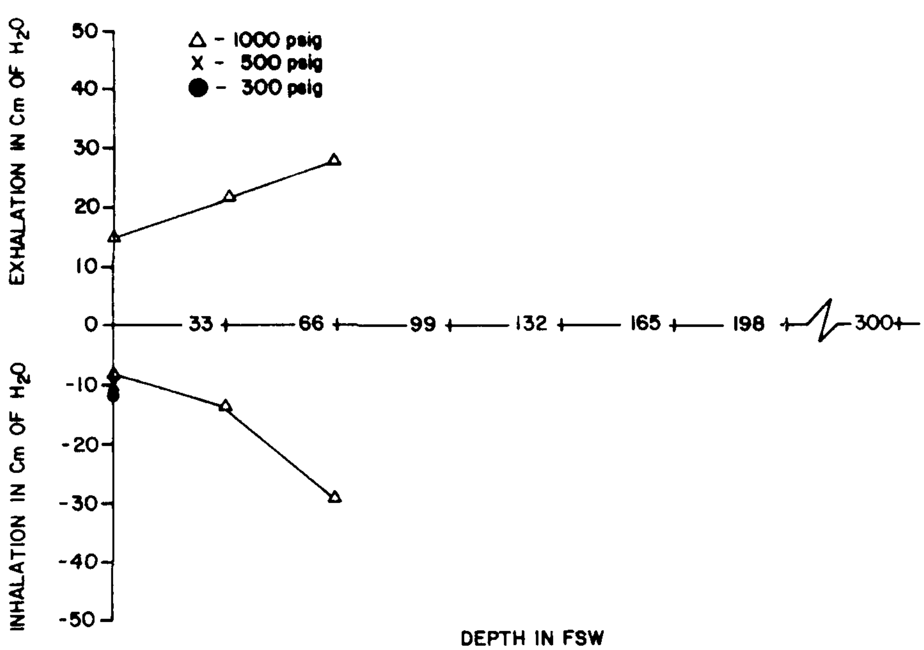


Figure 2B-5. Dacor Pacer 150
Breathing resistance vs. depth at 90 RMV

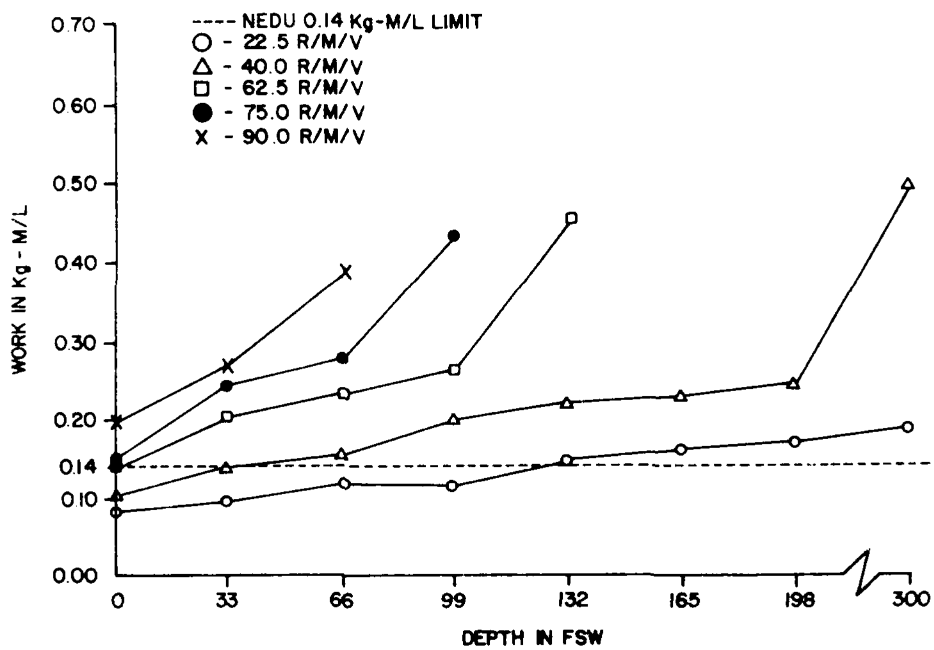


Figure 2B-6. Dacor Pacer 150
Breathing work vs. depth at 1000 psig supply pressure

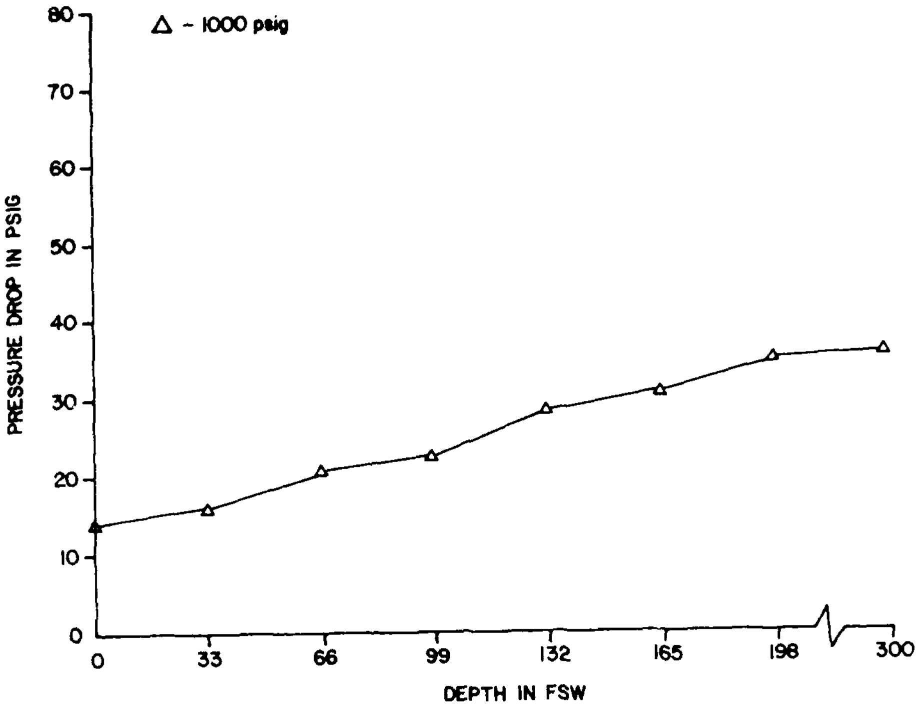


Figure 2B-7. Dacor Pacer 150
First stage pressure drop vs. depth at 22.5 RMV

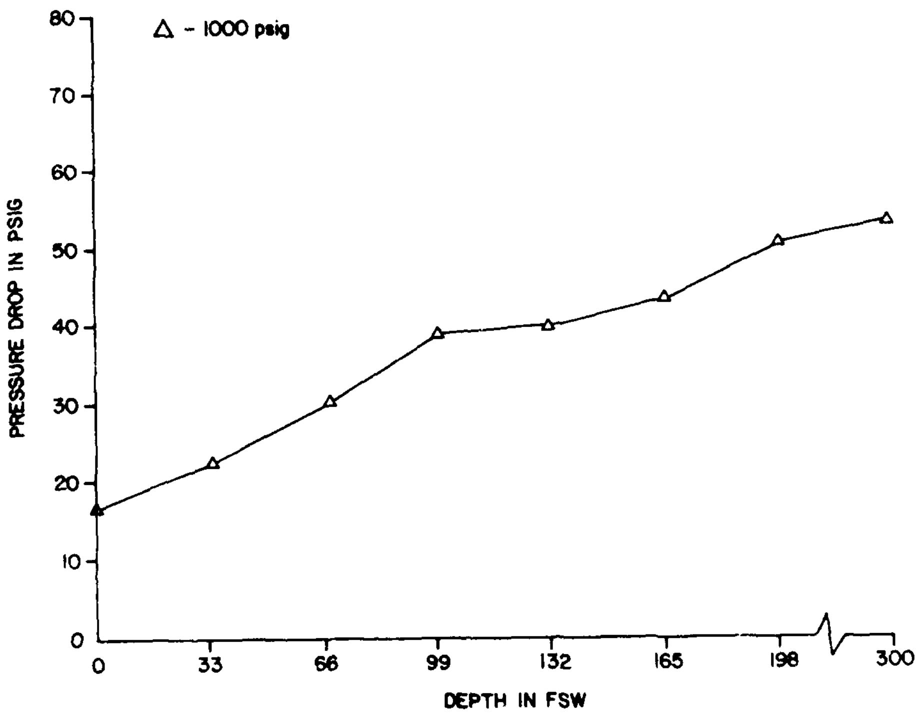


Figure 2B-8. Dacor Pacer 150
First stage pressure drop vs. depth at 40 RMV

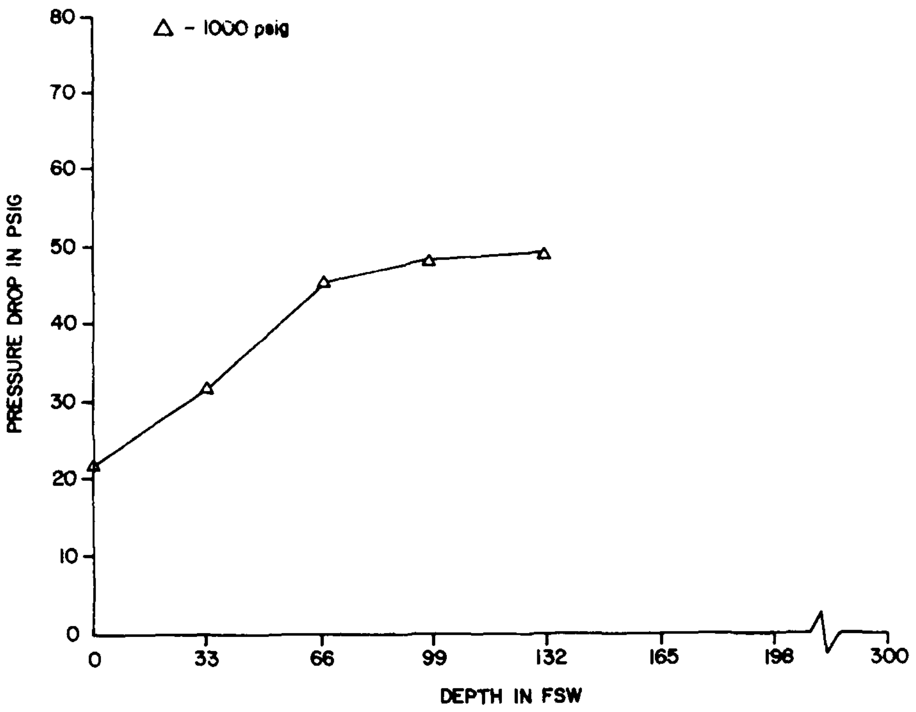


Figure 2B-9. Dacor Pacer 150
First stage pressure drop vs. depth at 62.5 RMV

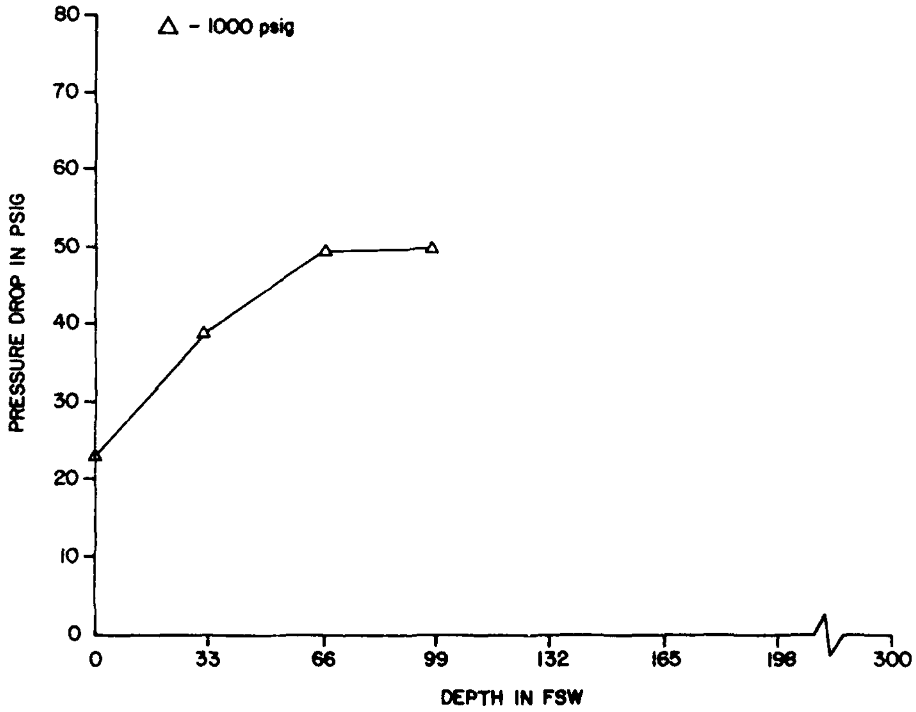


Figure 2B-10. Dacor Pacer 150
First stage pressure drop vs. depth at 75 RMV

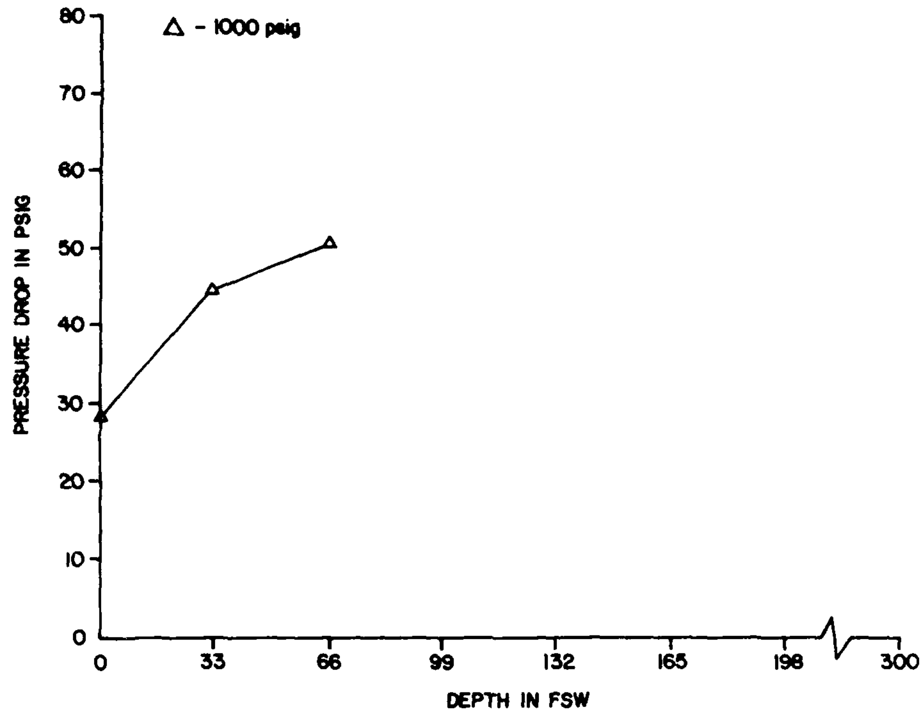


Figure 2B-11. Dacor Pacer 150
First stage pressure drop vs. depth at 90 RMV

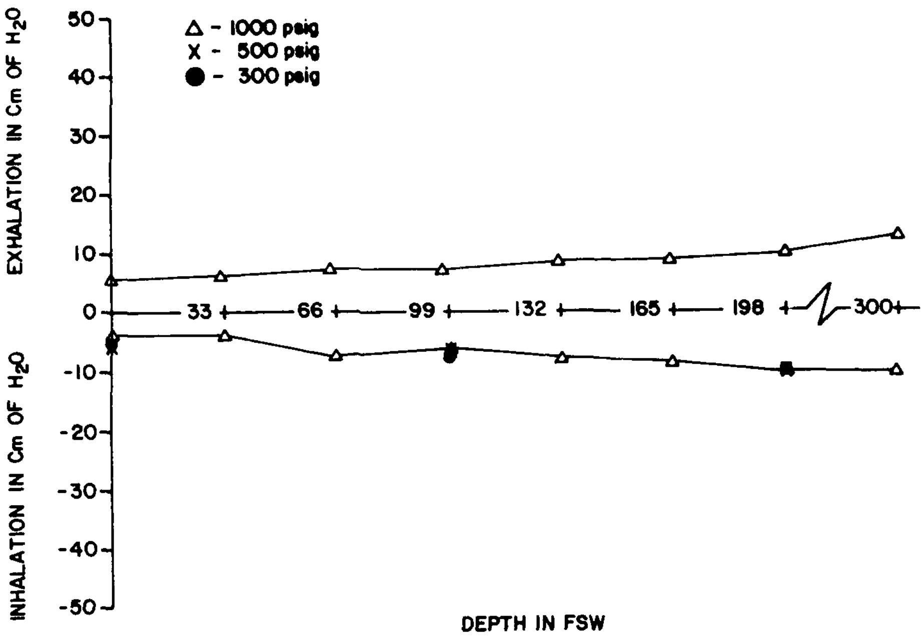


Figure 2C-1. Dacor Pacer 300
Breathing resistance vs. depth at 22.5 RMV

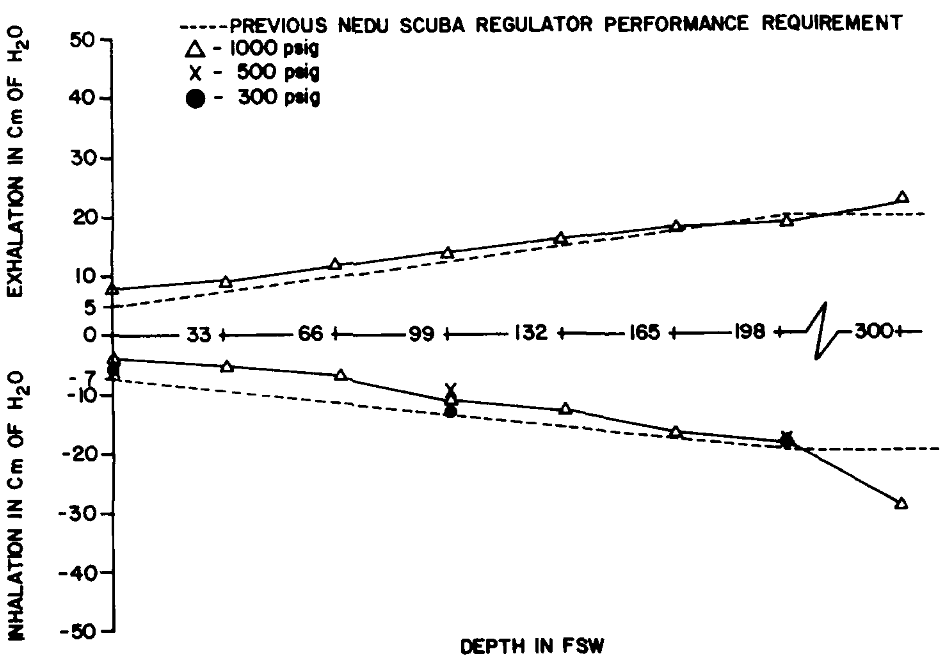


Figure 2C-2. Dacor Pacer 300
Breathing resistance vs. depth at 40 RMV

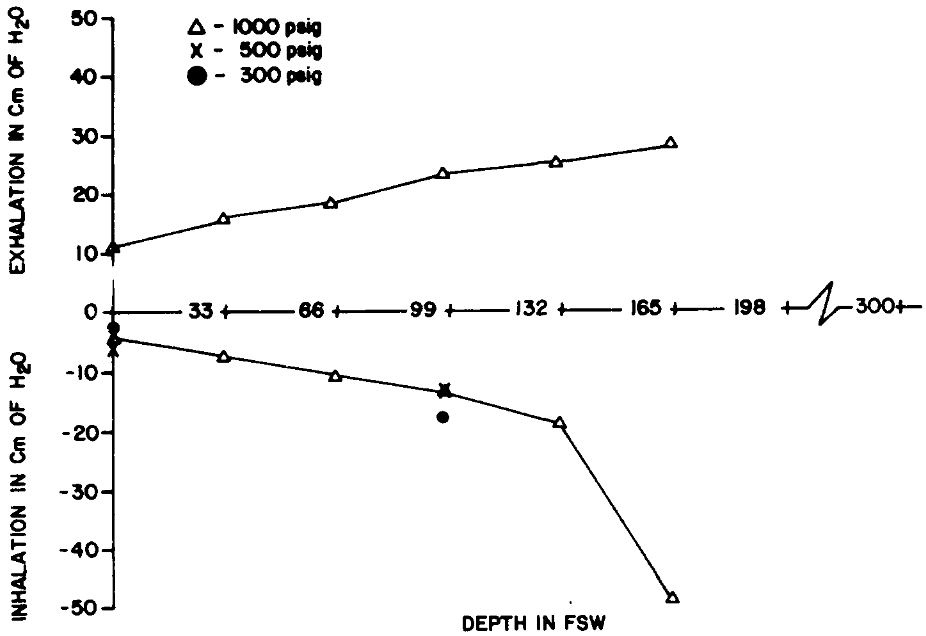


Figure 2C-3. Dacor Pacer 300
Breathing resistance vs. depth at 62.5 RMV

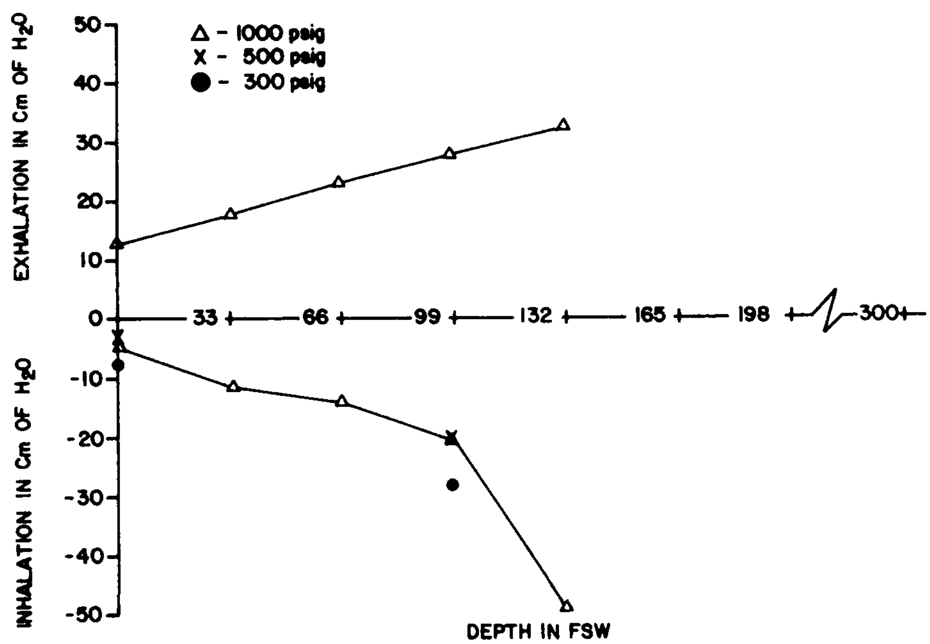


Figure 2C-4. Dacor Pacer 300
Breathing resistance vs. depth at 75 RMV

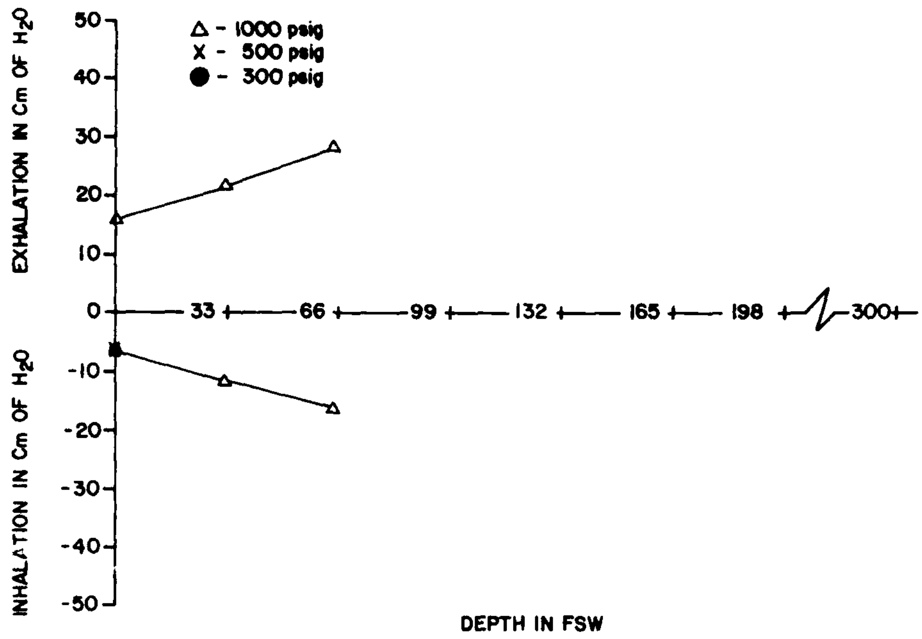


Figure 2C-5. Dacor Pacer 300
Breathing resistance vs. depth at 90 RMV

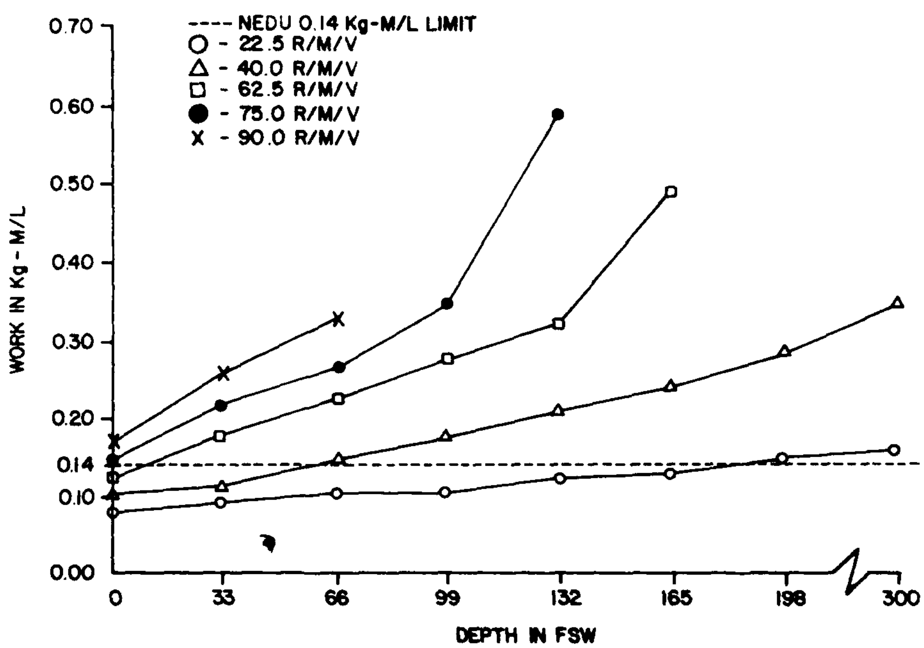


Figure 2C-6. Dacor Pacer 300
Breathing work vs. depth at 1000 psig supply pressure

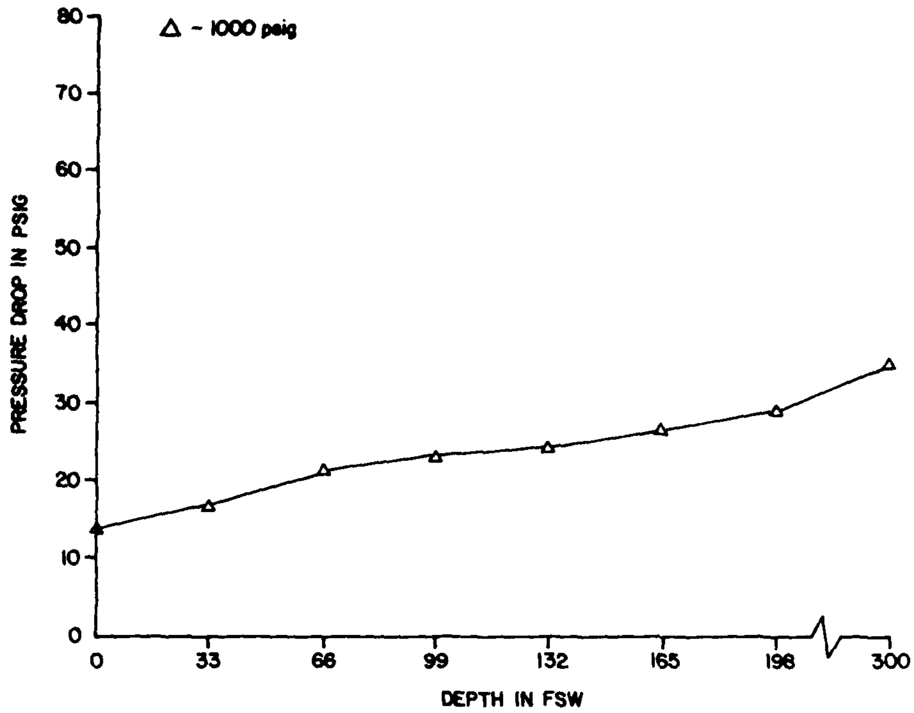


Figure 2C-7. Dacor Pacer 300
First stage pressure drop vs. depth at 22.5 RMV

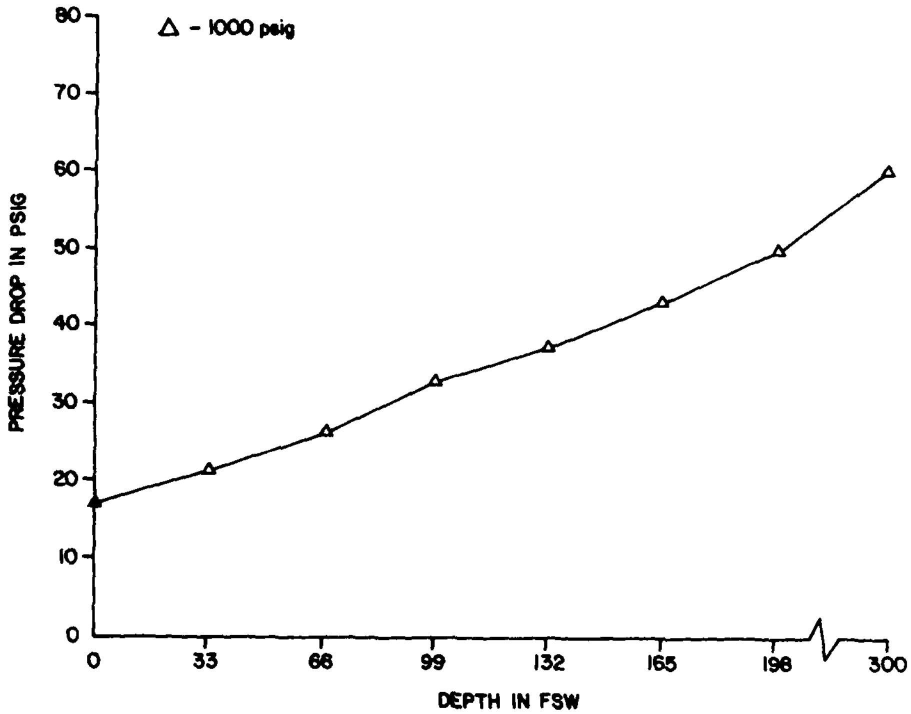


Figure 2C-8. Dacor Pacer 300
First stage pressure drop vs. depth at 40 RMV

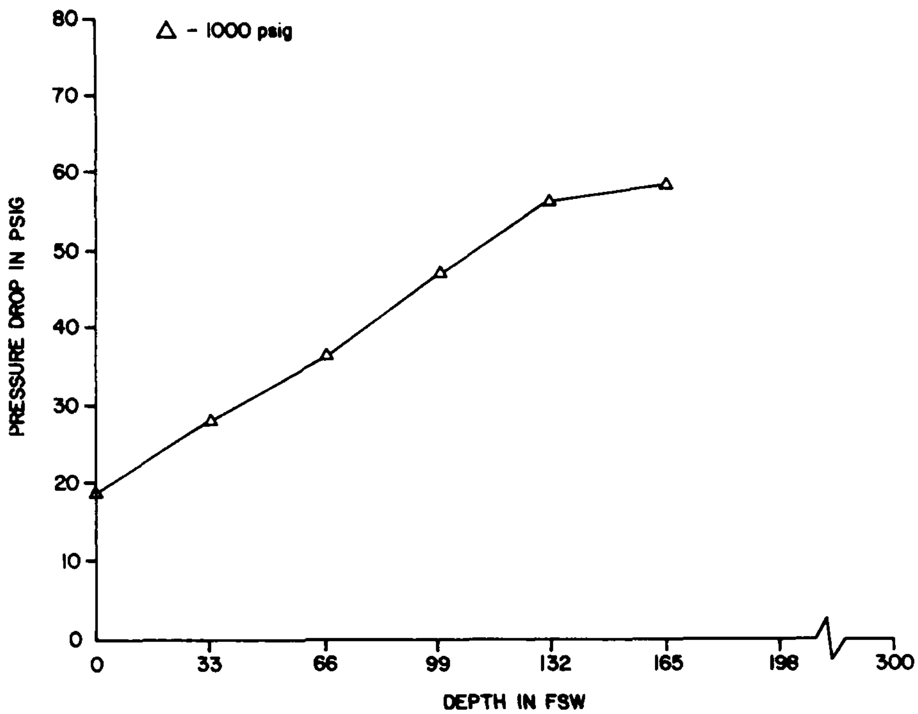


Figure 2C-9. Dacor Pacer 300
First stage pressure drop vs. depth at 62.5 RMV

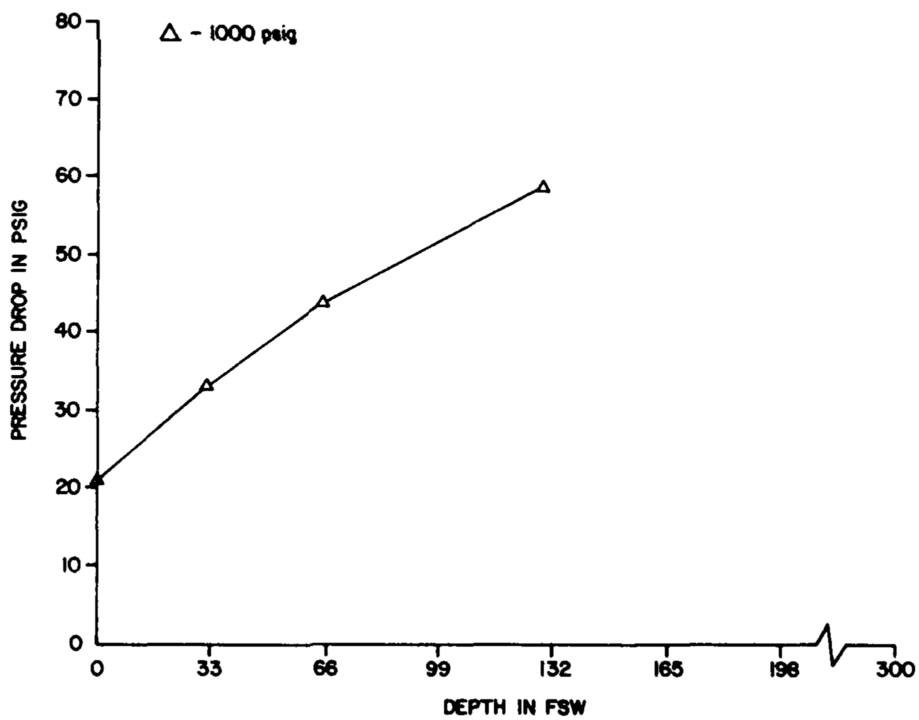


Figure 2C-10. Dacor Pacer 300
First stage pressure drop vs. depth at 75 RMV

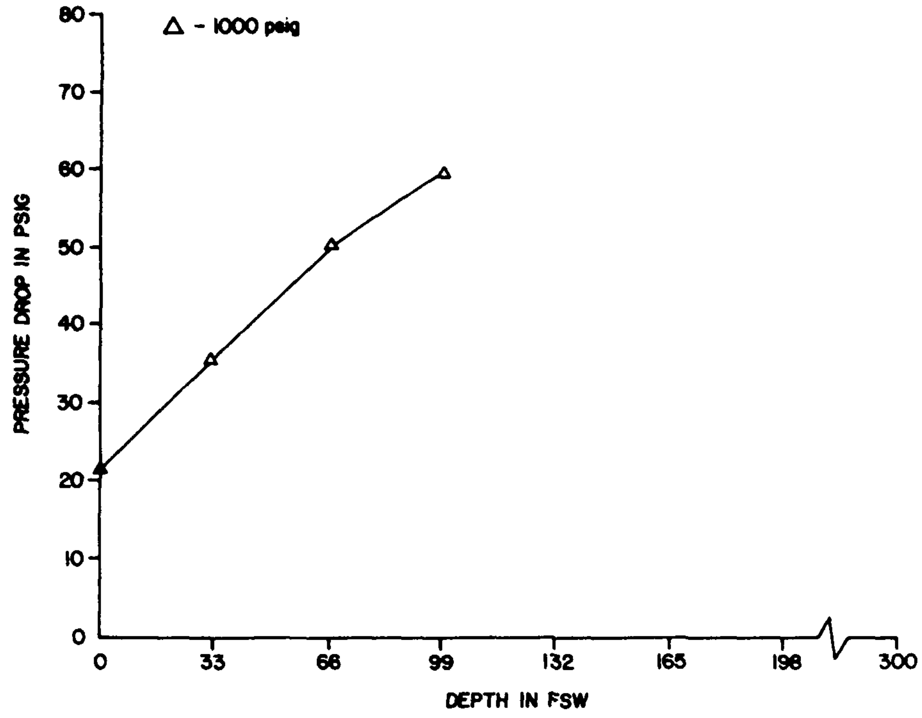


Figure 2C-11. Dacor Pacer 300
First stage pressure drop vs. depth at 90 RMV

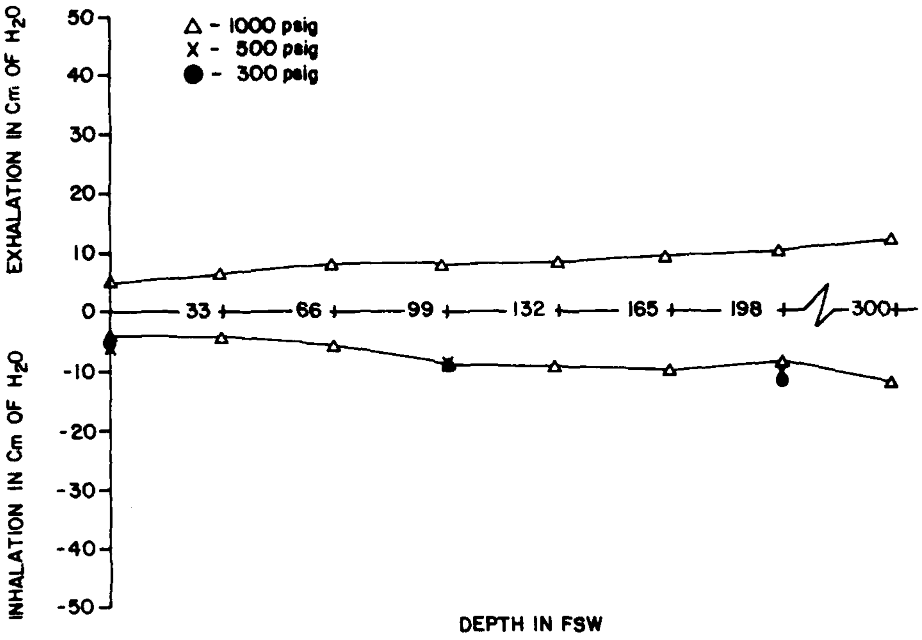


Figure 2D-1. Dacor Pacer 600
Breathing resistance vs. depth at 22.5 RMV

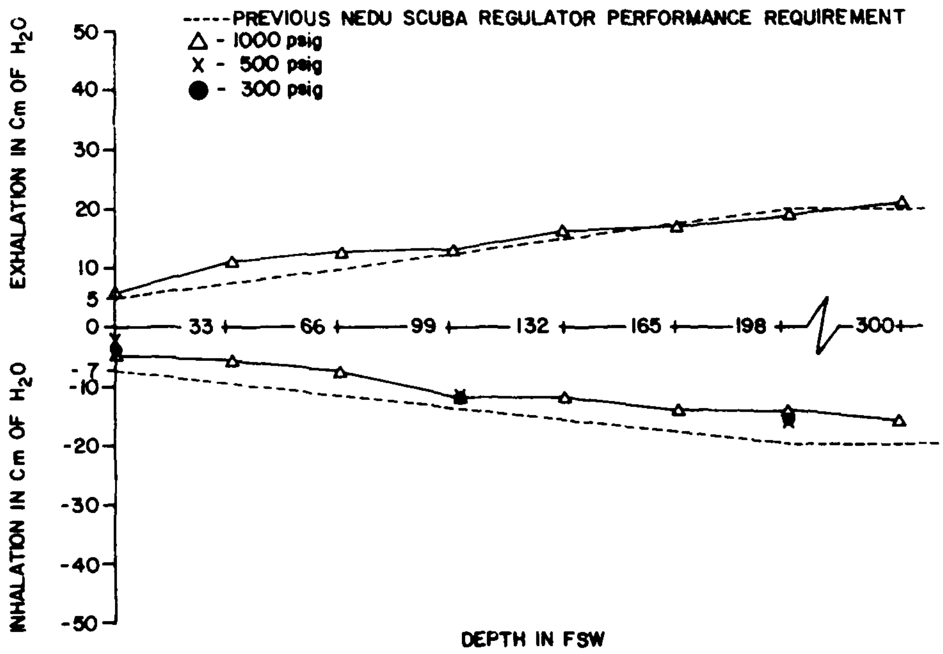


Figure 2D-2. Dacor Pacer 600
Breathing resistance vs. depth at 40 RMV

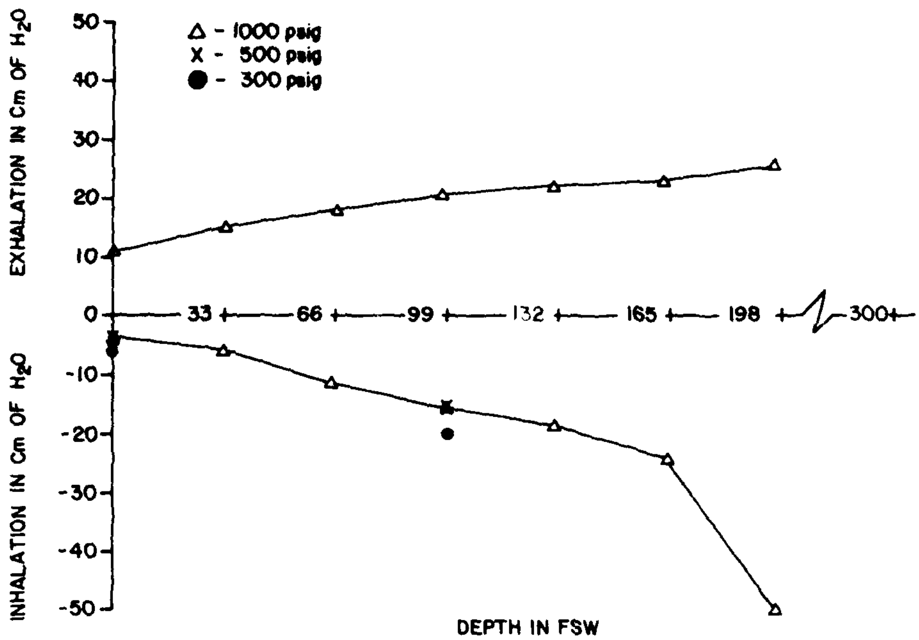


Figure 2D-3. Dacor Pacer 600
Breathing resistance vs. depth at 62.5 RMV

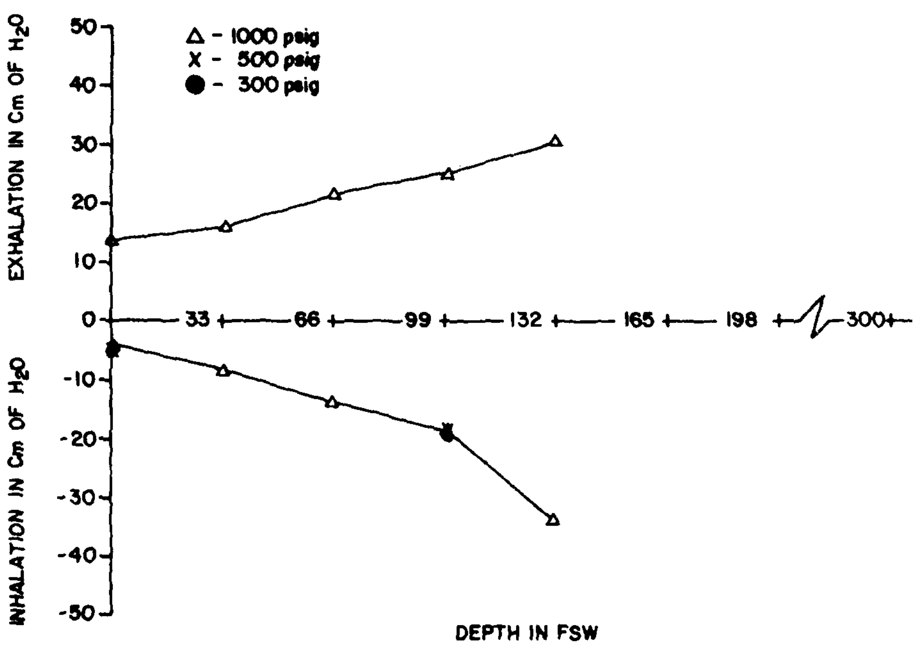


Figure 2D-4. Dacor Pacer 600
Breathing resistance vs. depth at 75 RMV

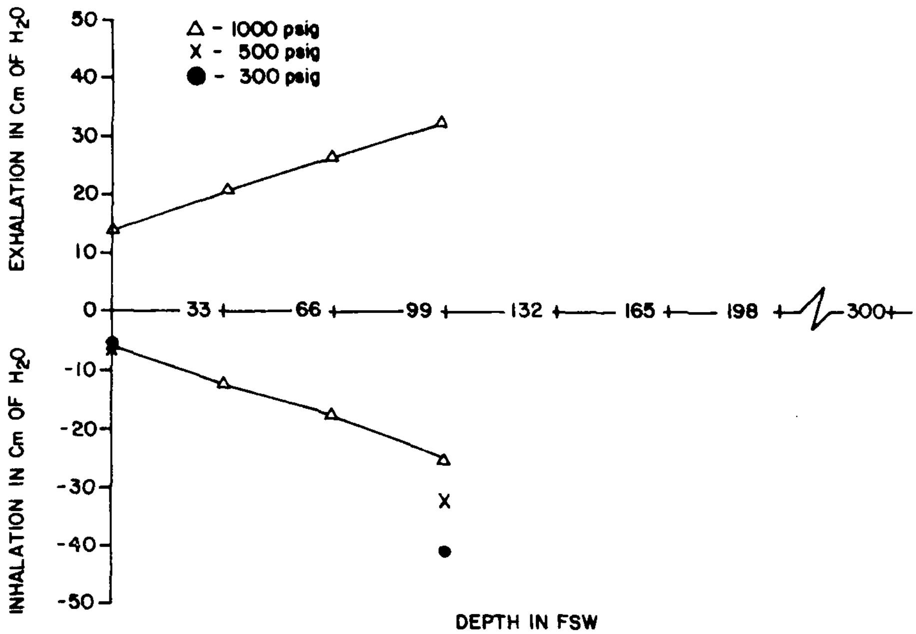


Figure 2D-5. Dacor Pacer 600
Breathing resistance vs. depth at 90 RMV

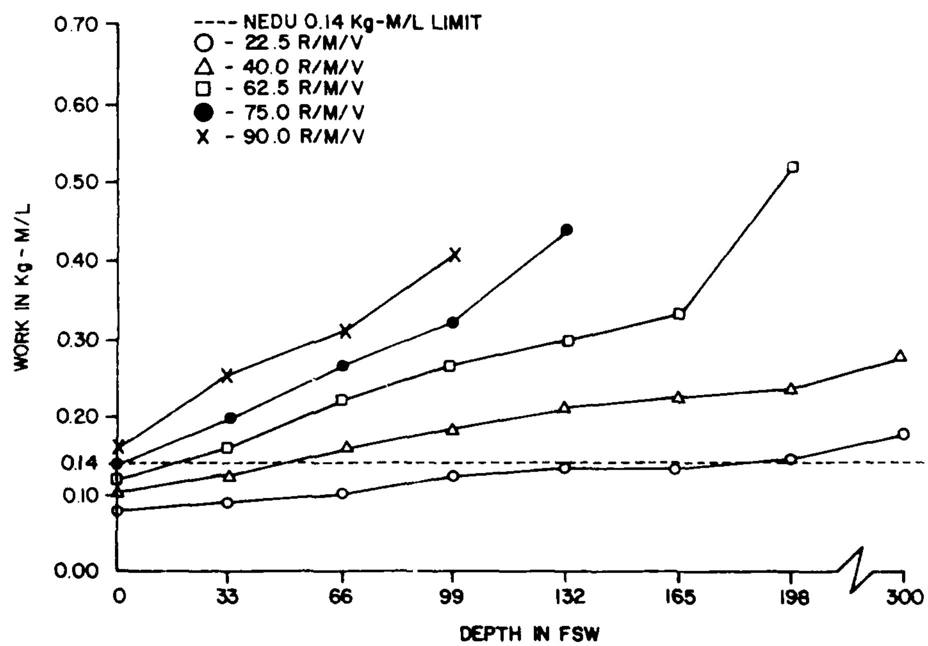


Figure 2D-6. Dacor Pacer 600
Breathing work vs. depth at 1000 psig supply pressure

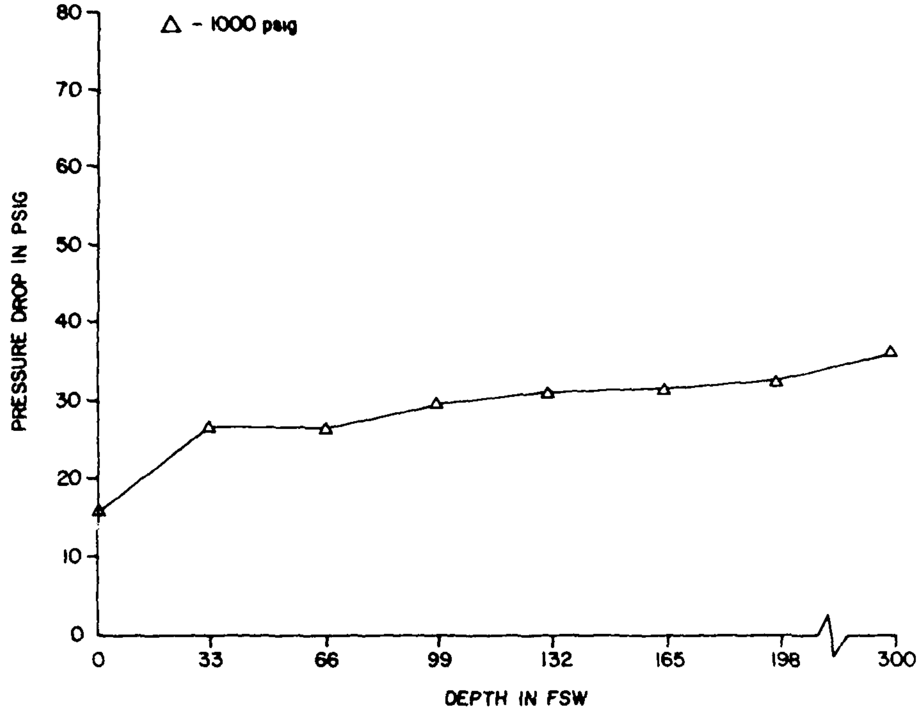


Figure 2D-7. Dacor Pacer 600
First stage pressure drop vs. depth at 22.5 RMV

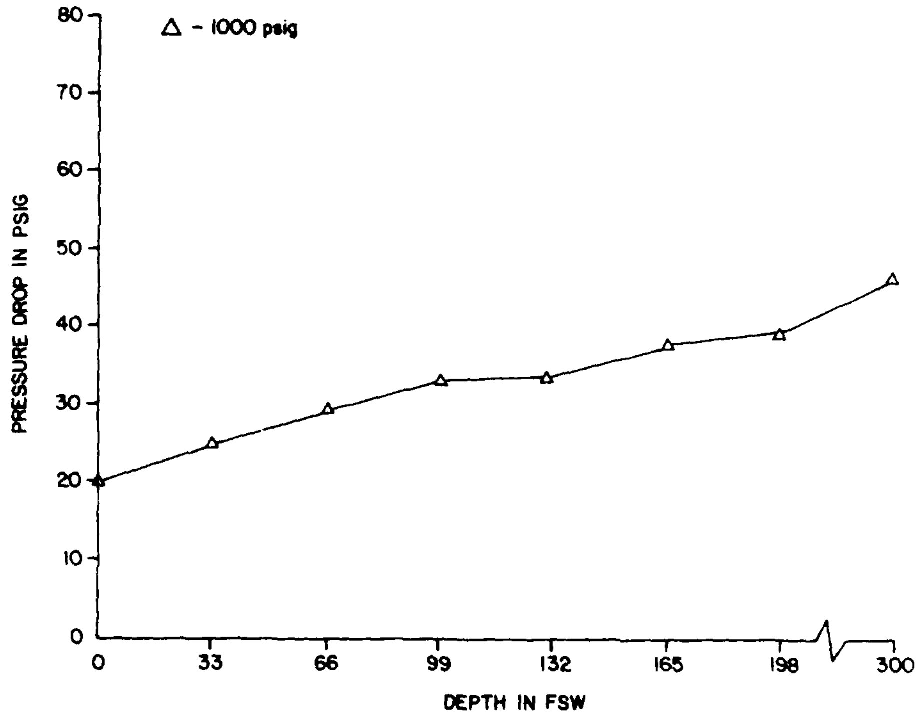


Figure 2D-8. Dacor Pacer 600
First stage pressure drop vs. depth at 40 RMV

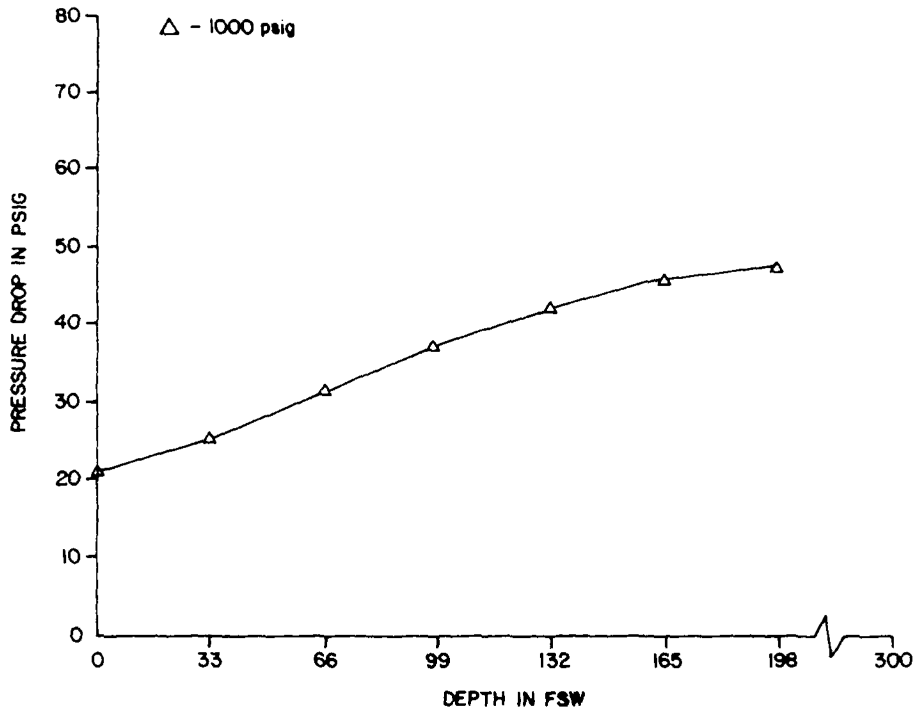


Figure 2D-9. Dacor Pacer 600
First stage pressure drop vs. depth at 62.5 RMV

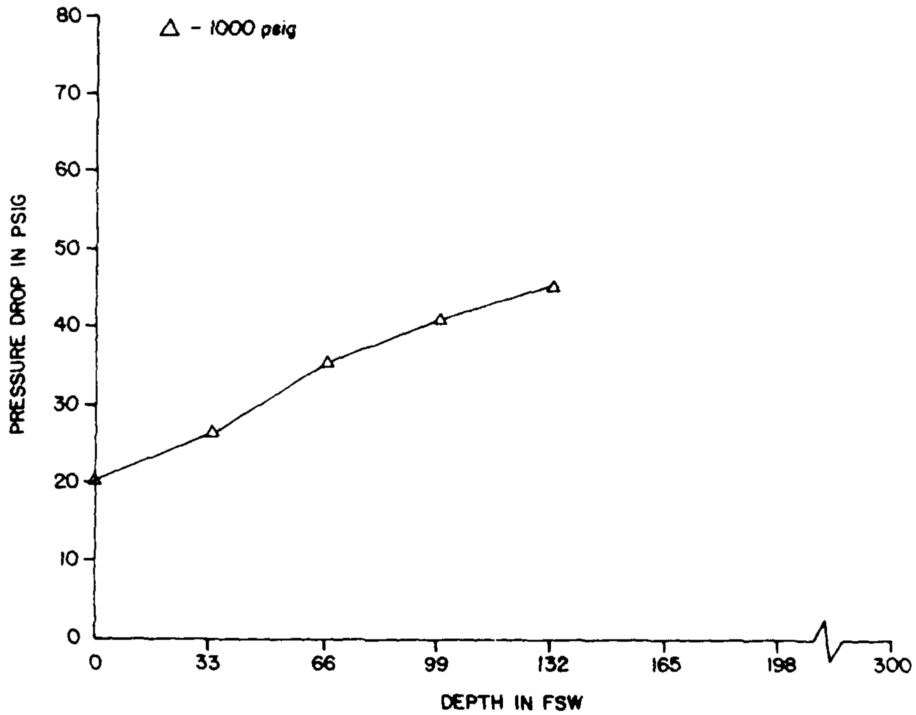


Figure 2D-10. Dacor Pacer 600
First stage pressure drop vs. depth at 75 RMV

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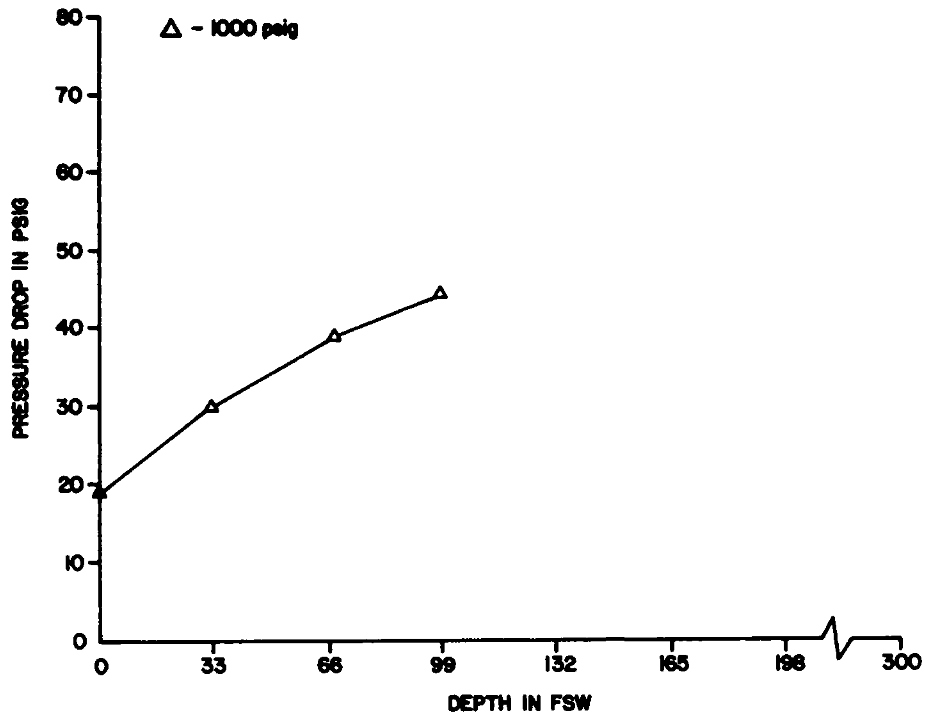

Figure 2D-11. Dacor Pacer 600
First stage pressure drop vs. depth at 90 RMV

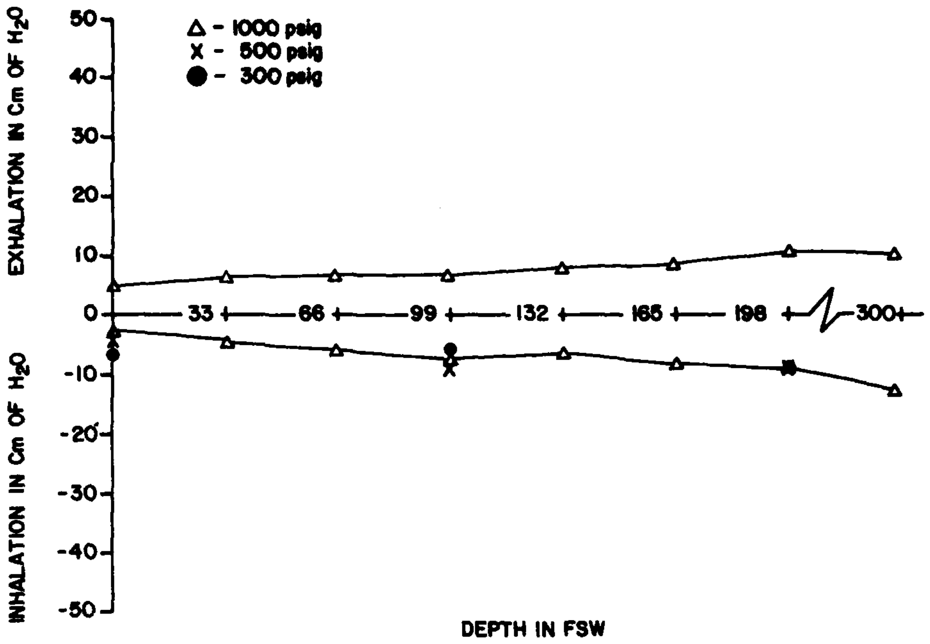

Figure 2E-1. Dacor Pacer 900
Breathing resistance vs. depth at 22.5 RMV

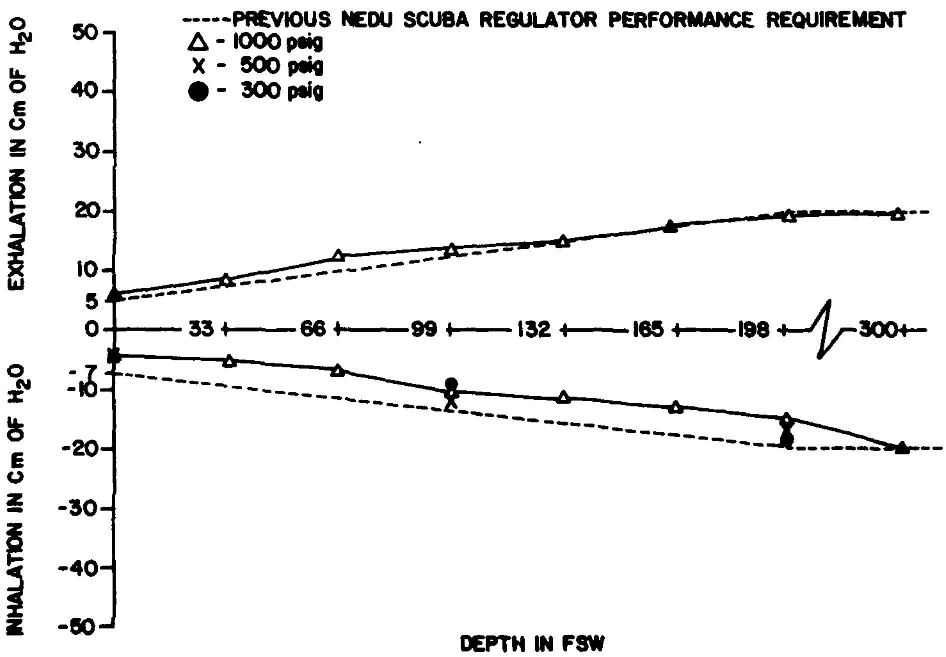

Figure 2E-2. Dacor Pacer 900
Breathing resistance vs. depth at 40 RMV

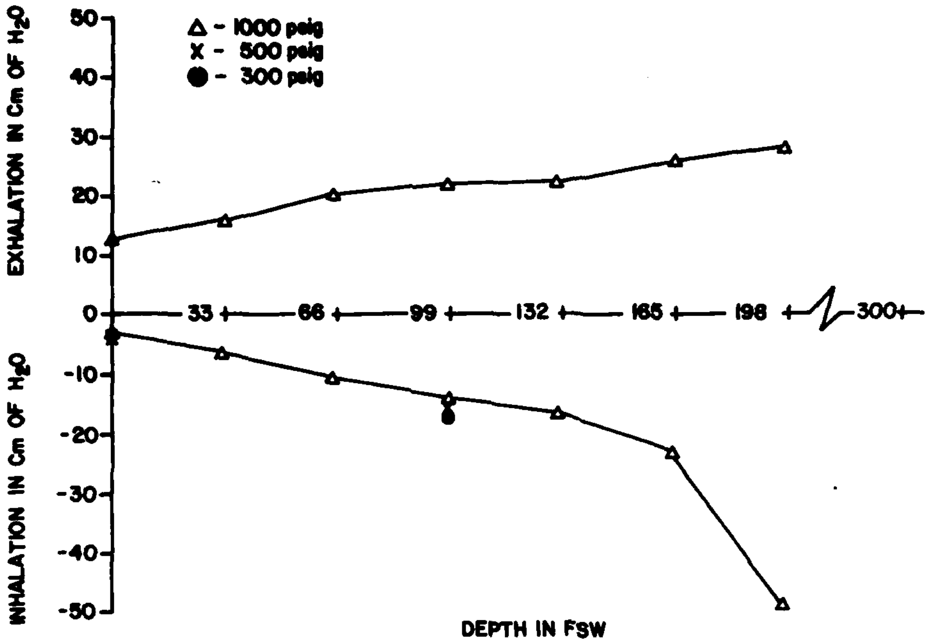

Figure 2E-3. Dacor Pacer 900
Breathing resistance vs. depth at 62.5 RMV

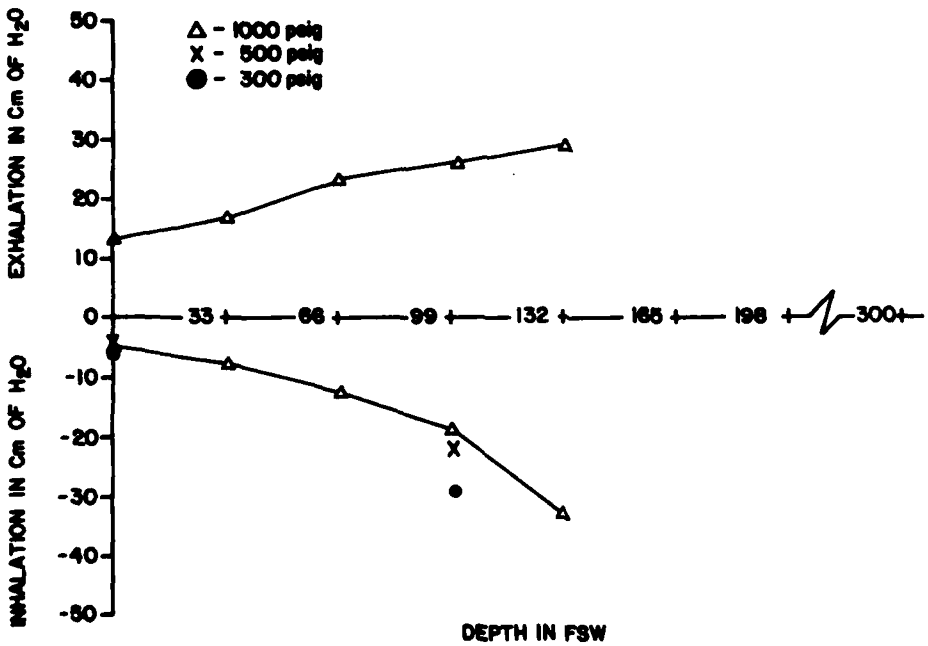

Figure 2E-4. Dacor Pacer 900
Breathing resistance vs. depth at 75 RMV

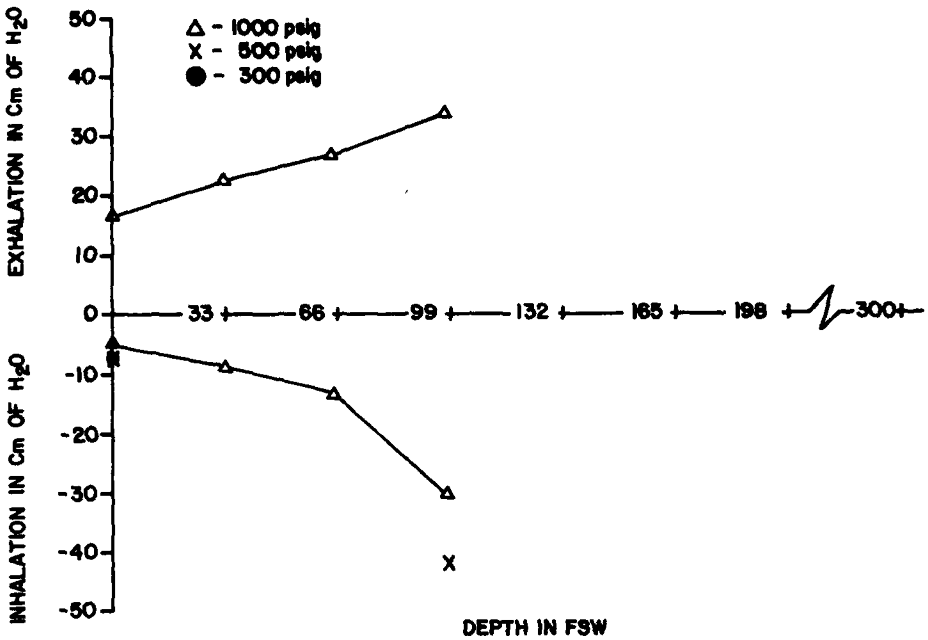

Figure 2E-5. Dacor Pacer 900
Breathing resistance vs. depth at 90 RMV

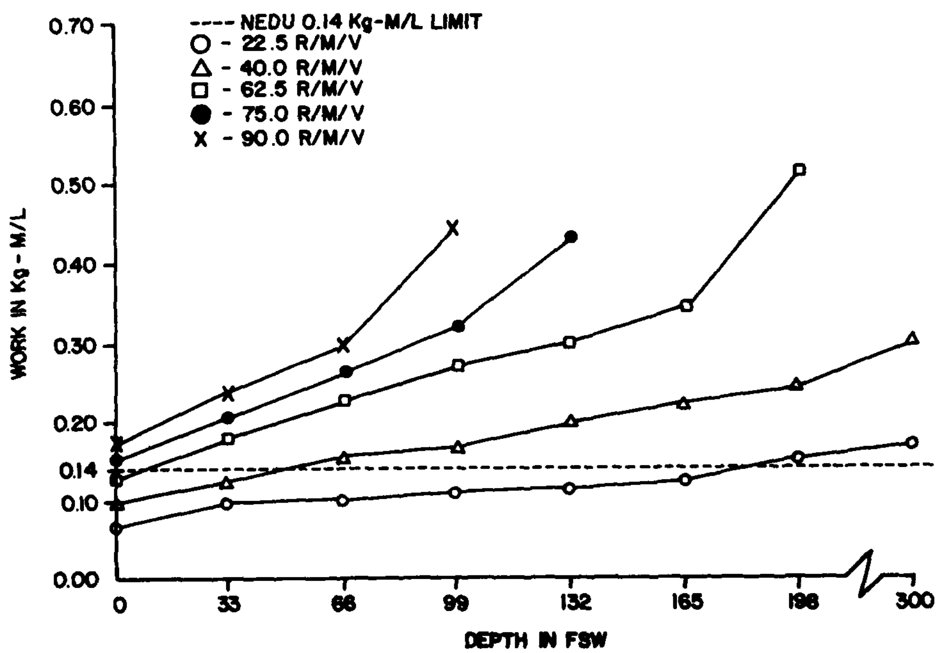

Figure 2E-6. Dacor Pacer 900
Breathing work vs. depth at 1000 psig supply pressure

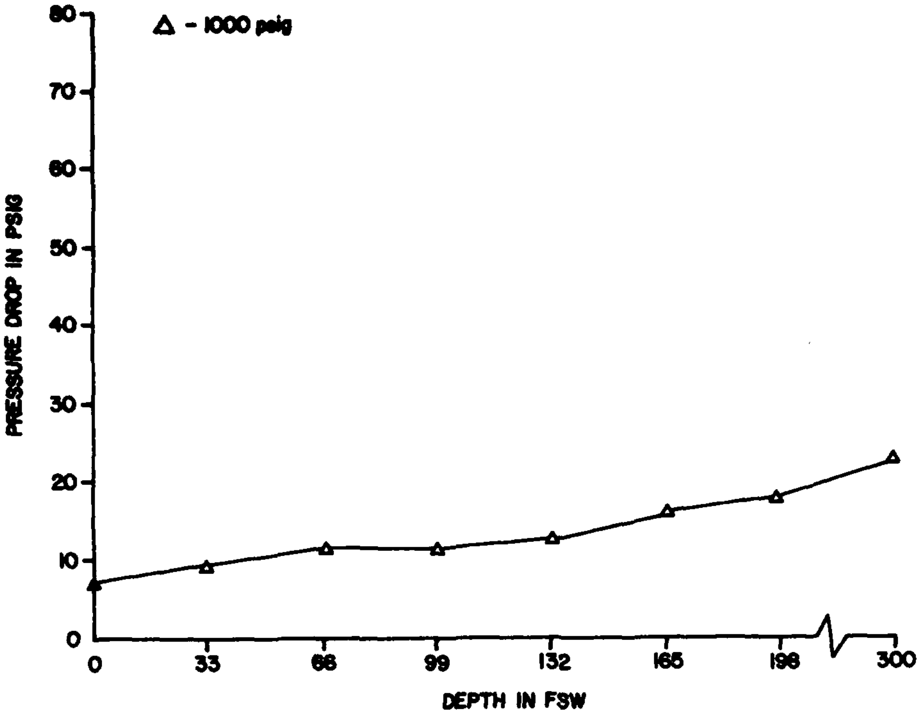

Figure 2E-7. Dacor Pacer 900
First stage pressure drop vs. depth at 22.5 RMV

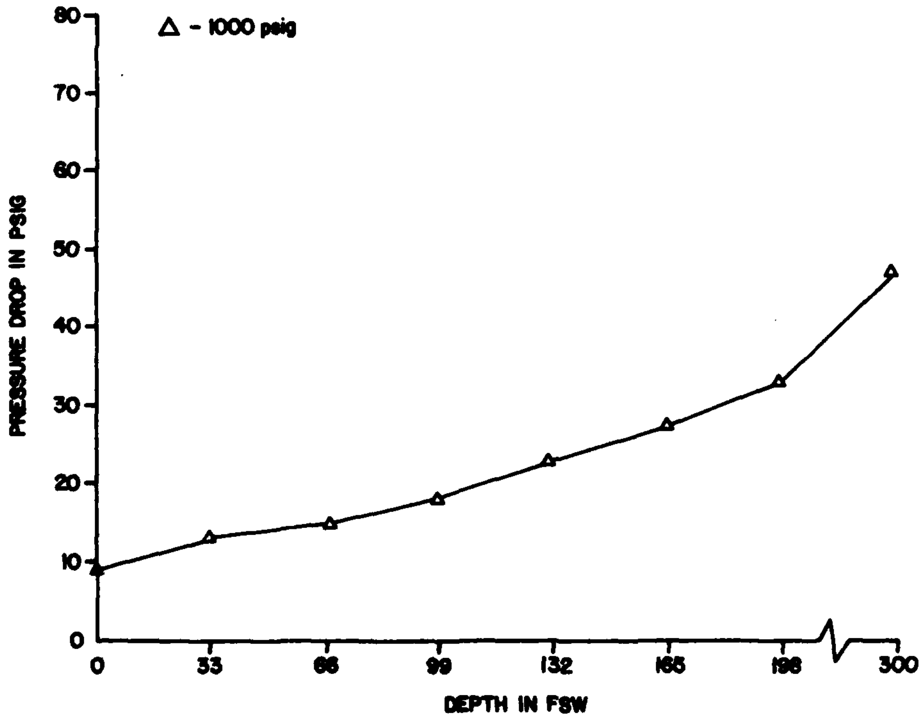

Figure 2E-8. Dacor Pacer 900
First stage pressure drop vs. depth at 40 RMV

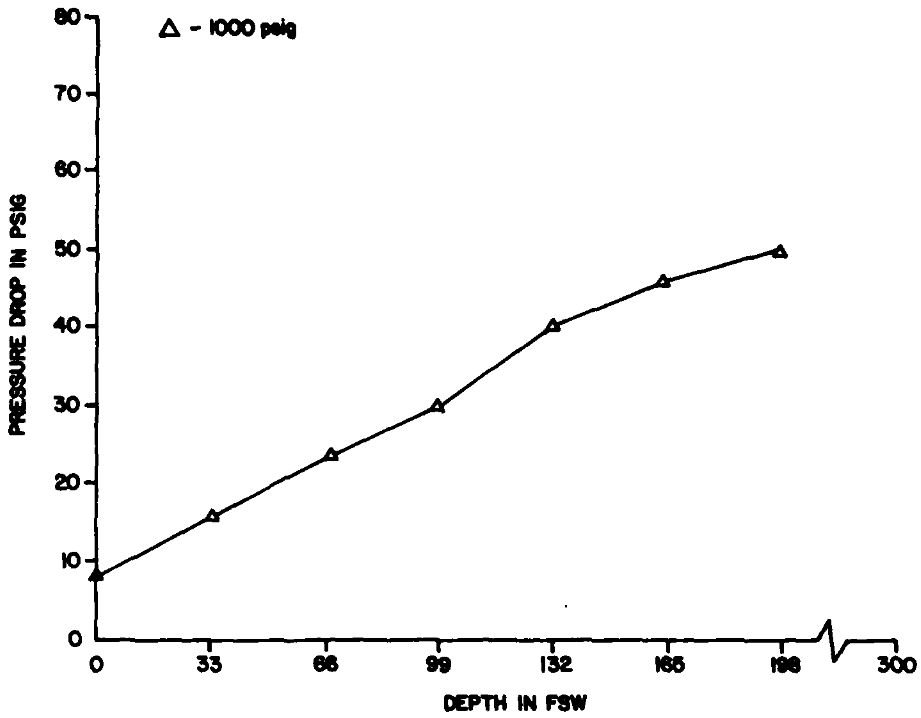

Figure 2E-9. Dacor Pacer 900
First stage pressure drop vs. depth at 62.5 RMV

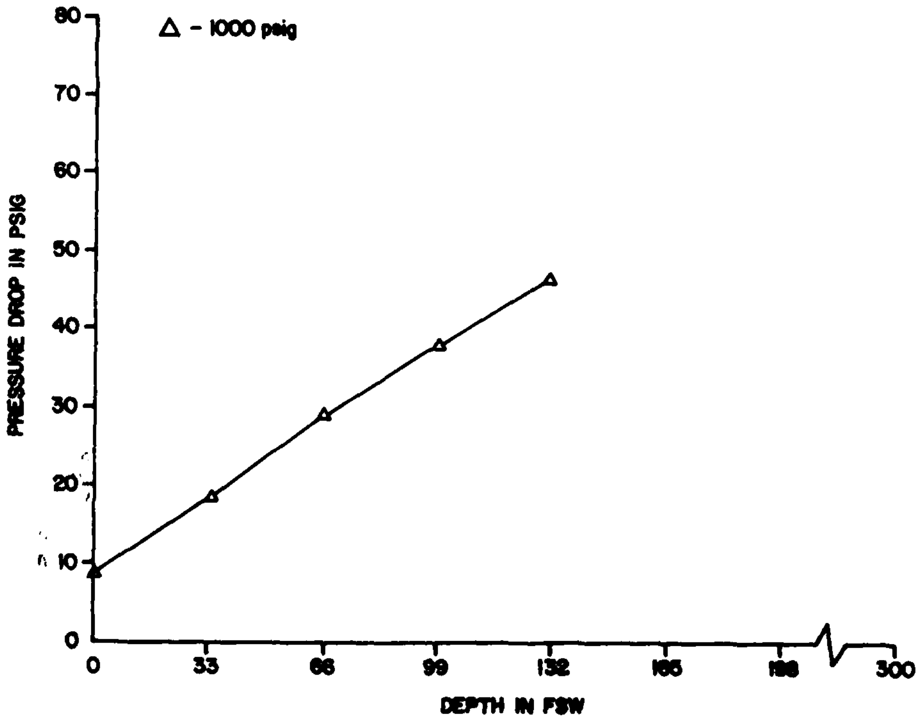

Figure 2E-10. Dacor Pacer 900
First stage pressure drop vs. depth at 75 RMV

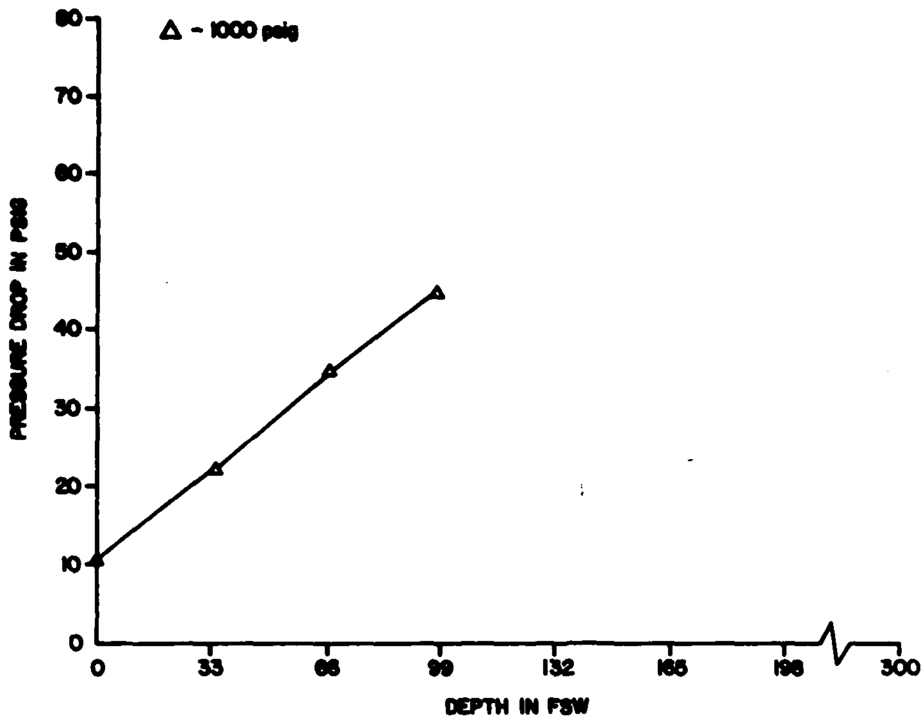

Figure 2E-11. Dacor Pacer 900
First stage pressure drop vs. depth at 90 RMV

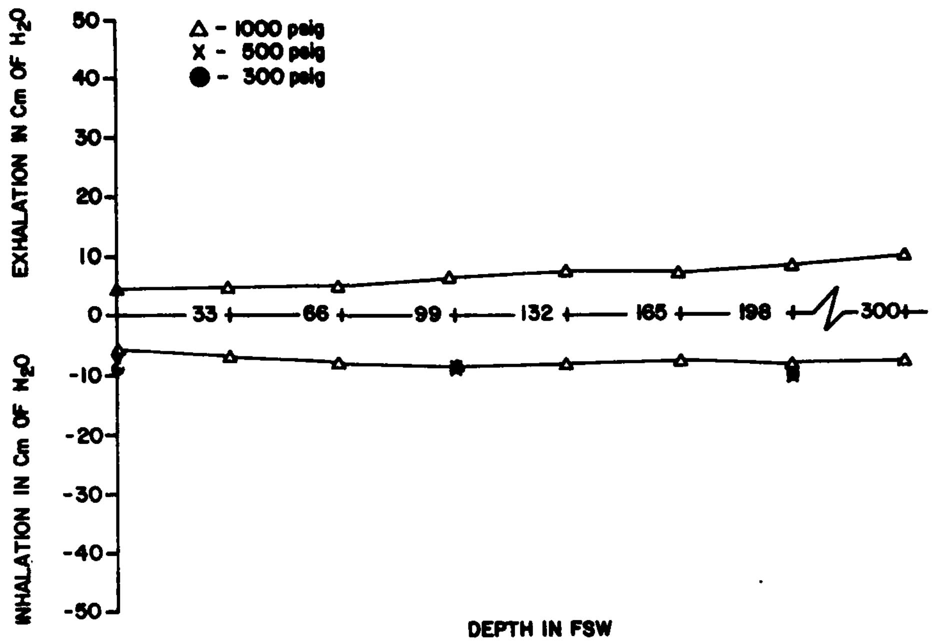

Figure 3A-1. Jepsen Model 200
Breathing resistance vs. depth at 22.5 RMV

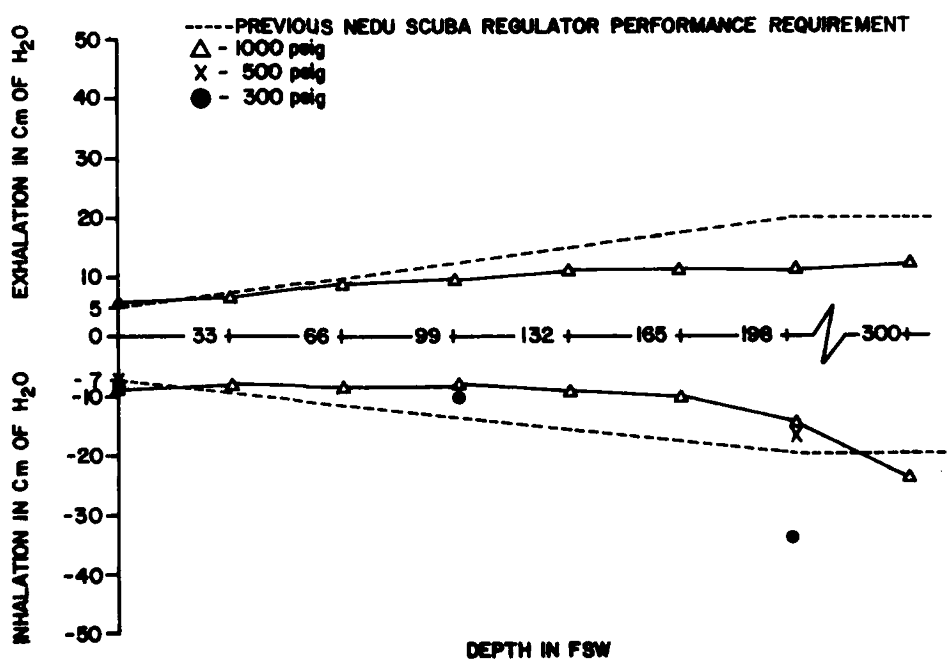

Figure 3A-2. Jepsen Model 200
Breathing resistance vs. depth at 40 RMV

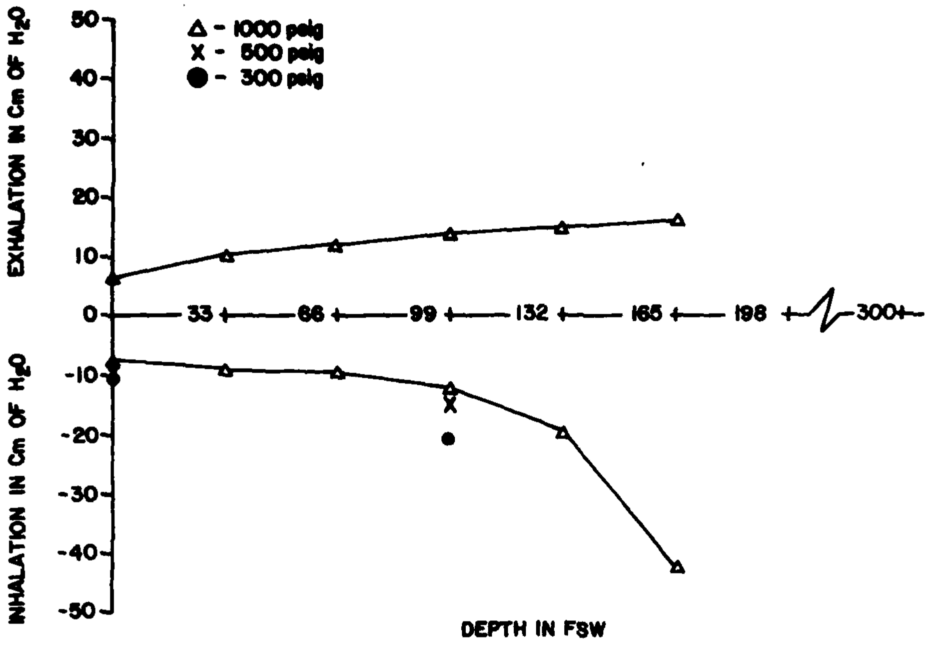

Figure 3A-3. Jepsen Model 200
Breathing resistance vs. depth at 62.5 RMV

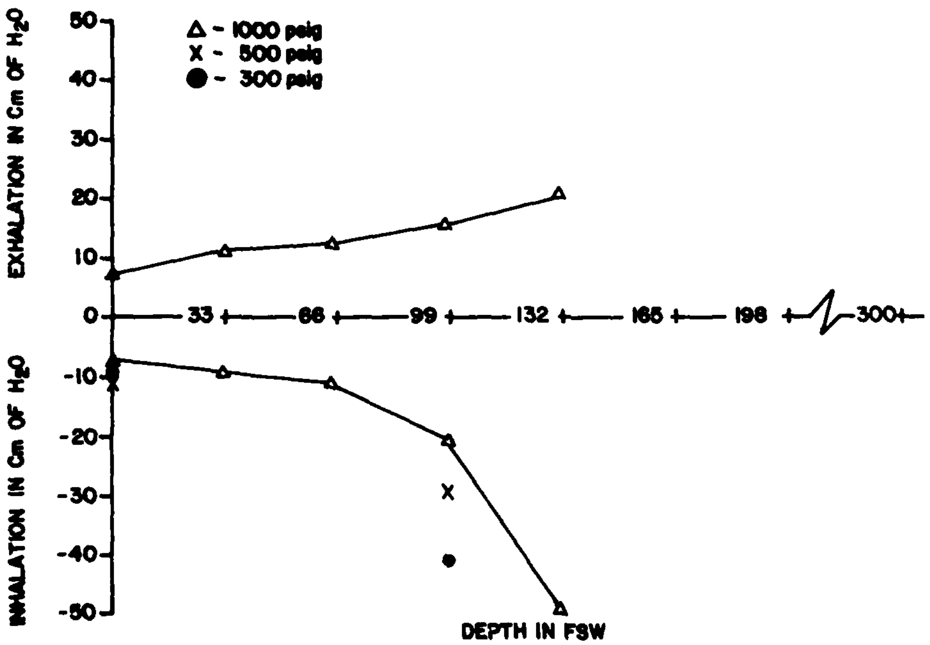

Figure 3A-4. Jepsen Model 200
Breathing resistance vs. depth at 75 RMV

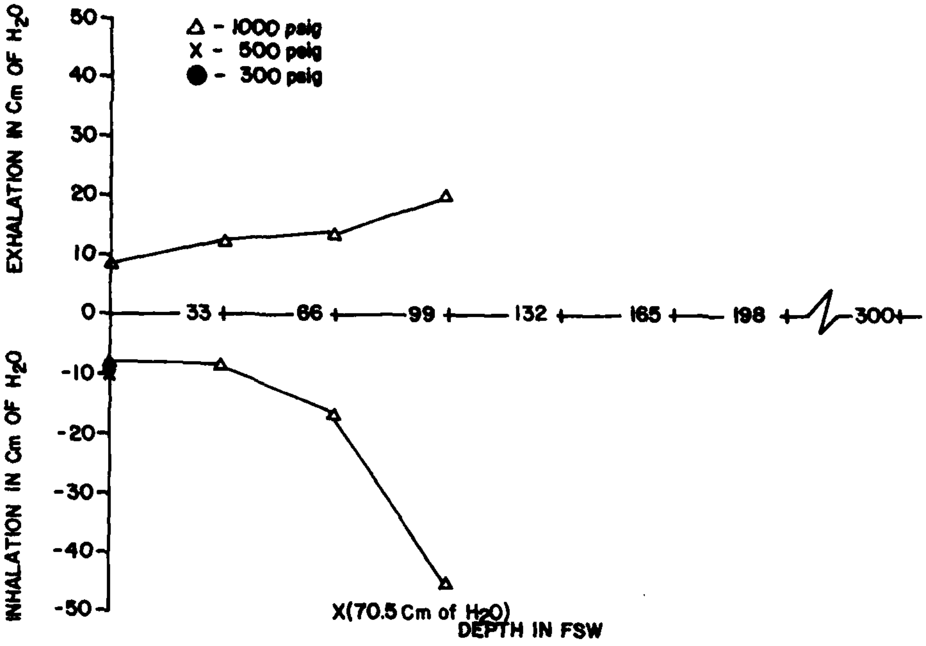

Figure 3A-5. Jepsen Model 200
Breathing resistance vs. depth at 90 RMV

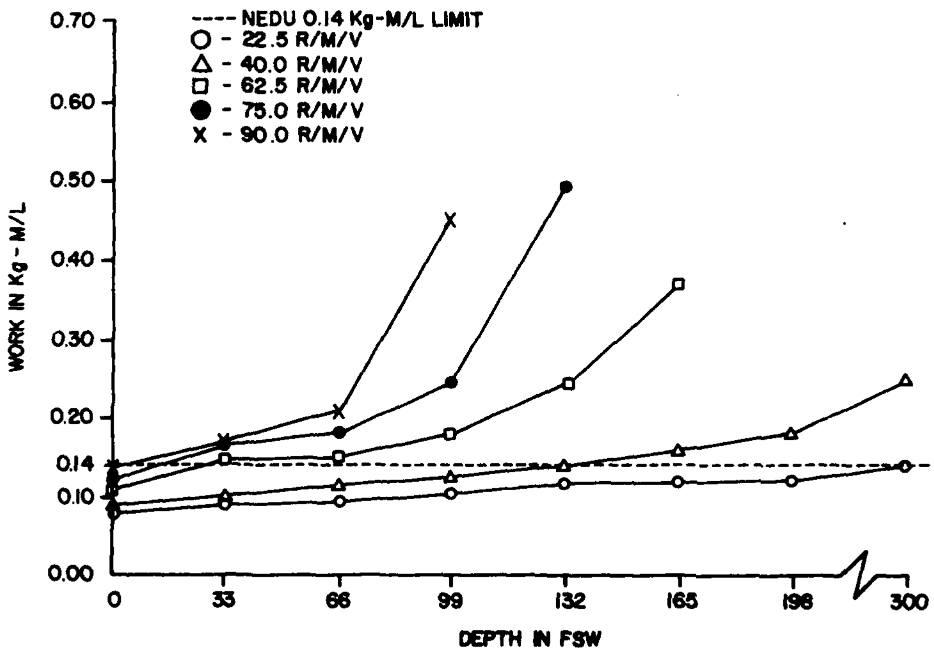

Figure 3A-6. Jepsen Model 200
Breathing work vs. depth at 1000 psig supply pressure

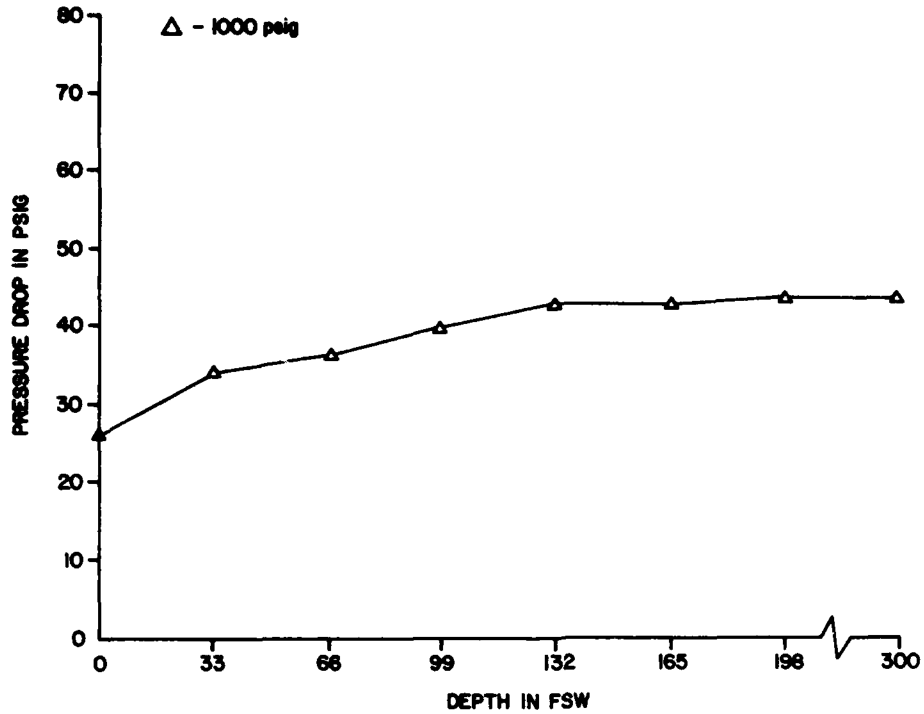

Figure 3A-7. Jepsen Model 200
First stage pressure drop vs. depth at 22.5 RMV

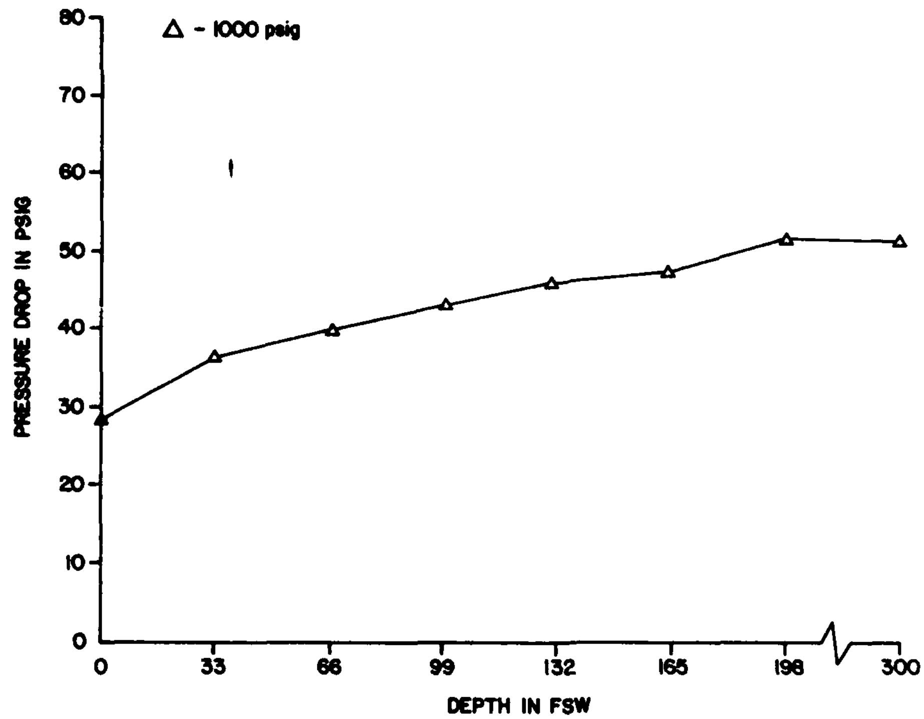

Figure 3A-8. Jepsen Model 200
First stage pressure drop vs. depth at 40 RMV

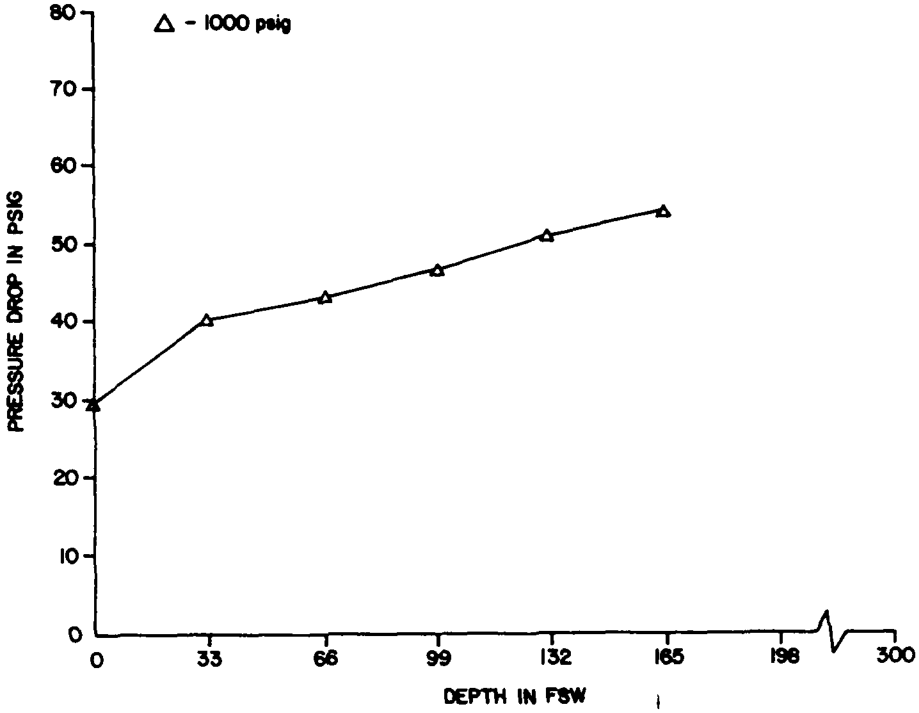

Figure 3A-9. Jepsen Model 200
First stage pressure drop vs. depth at 62.5 RMV

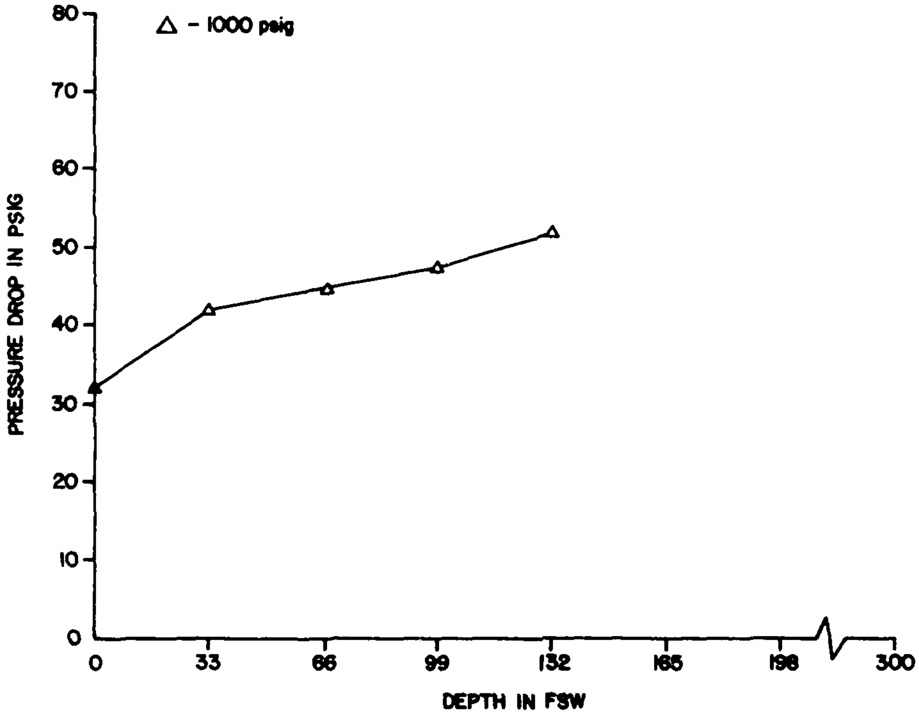

Figure 3A-10. Jepsen Model 200
First stage pressure drop vs. depth at 75 RMV

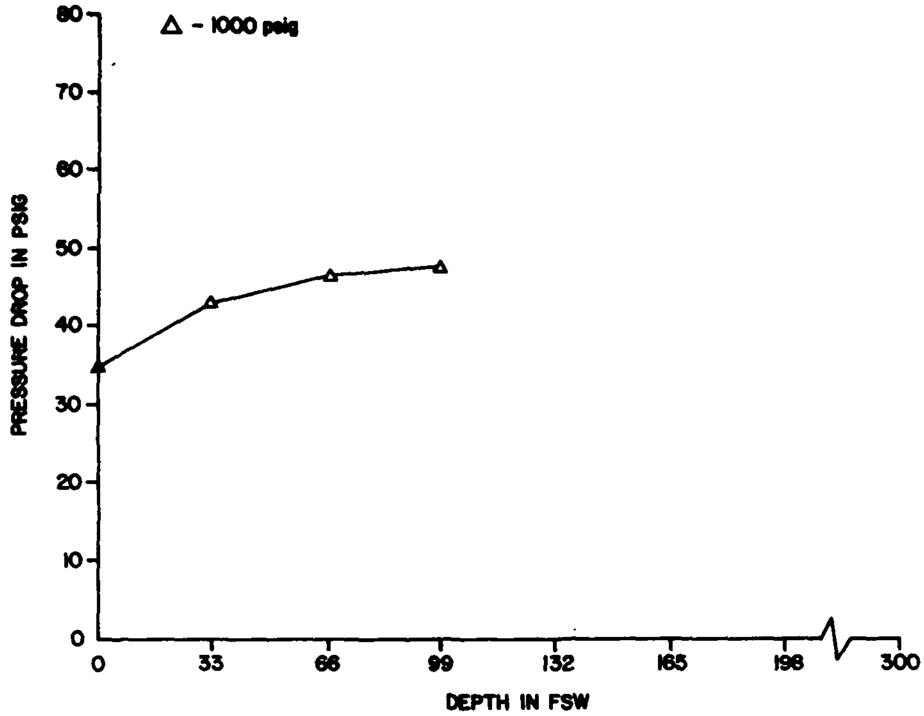

Figure 3A-11. Jepsen Model 200
First stage pressure drop vs. depth at 90 RMV

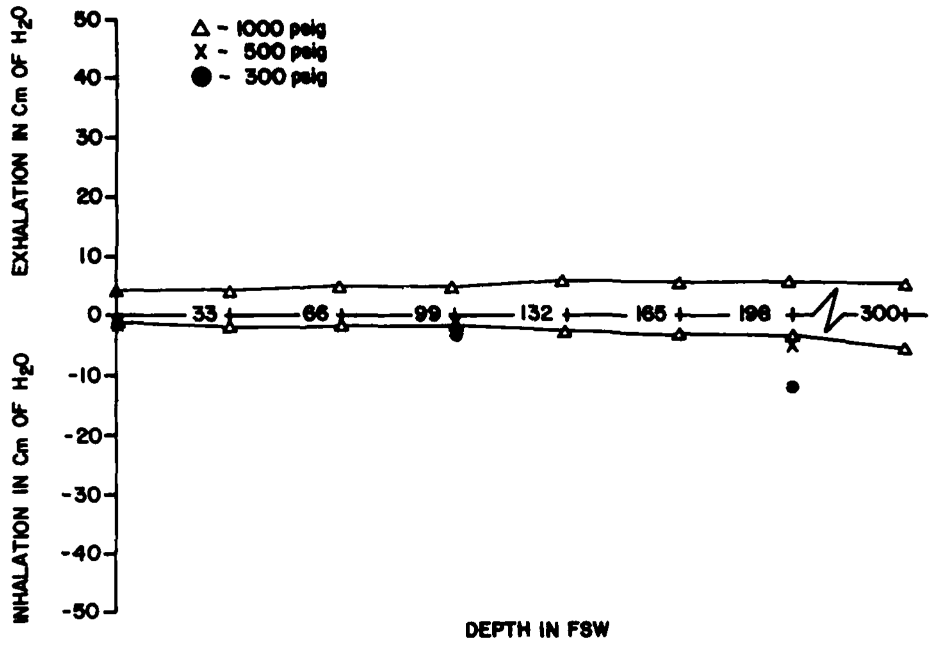

Figure 4A-1. Poseidon Cyclon 300
Breathing resistance vs. depth at 22.5 RMV

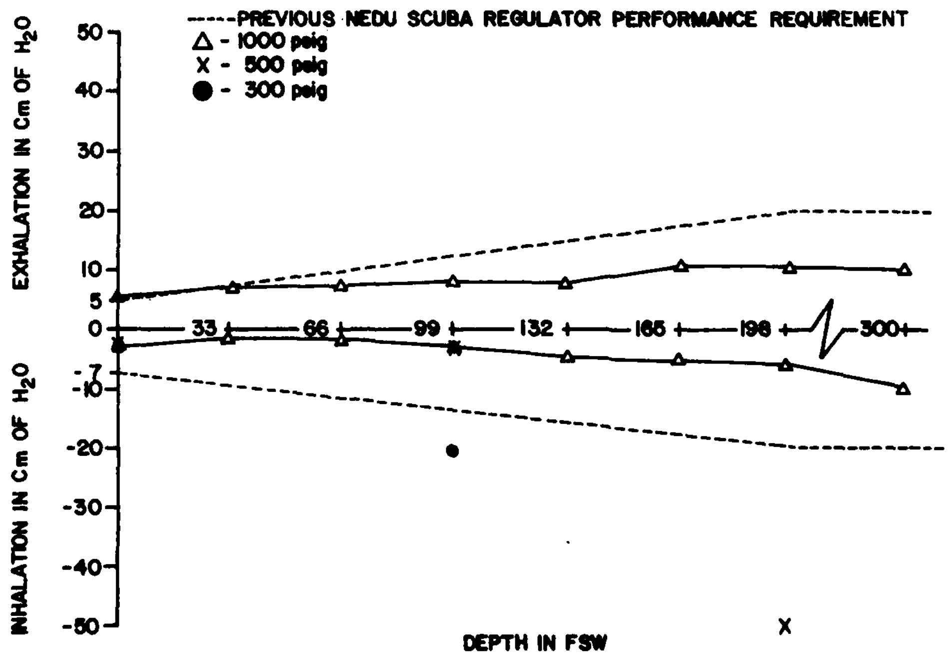

Figure 4A-2. Poseidon Cyclon 300
Breathing resistance vs. depth at 40 RMV

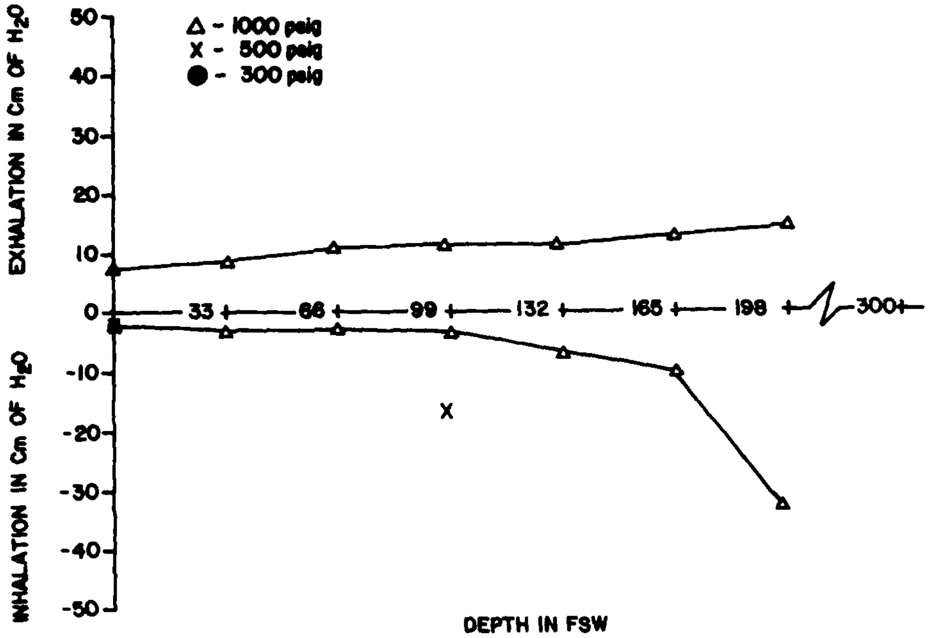

Figure 4A-3. Poseidon Cyclon 300
Breathing resistance vs. depth at 62.5 RMV

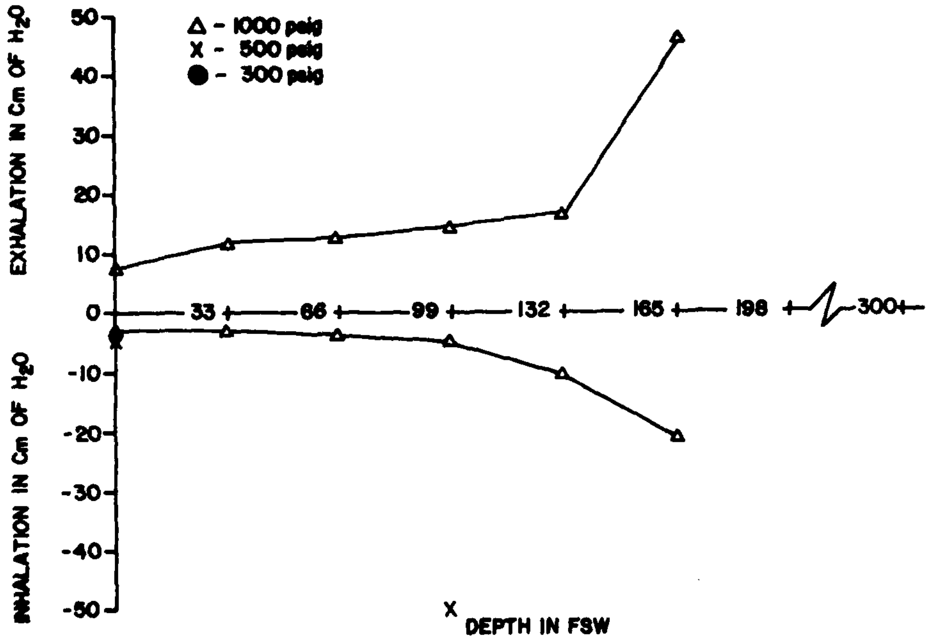

Figure 4A-4. Poseidon Cyclon 300
Breathing resistance vs. depth at 75 RMV

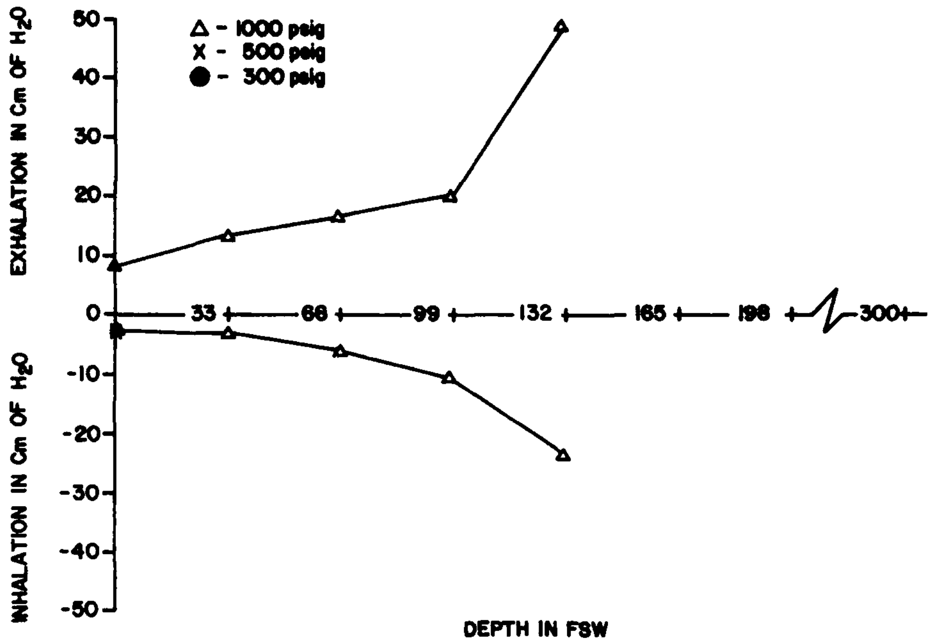

Figure 4A-5. Poseidon Cyclon 300
Breathing resistance vs. depth at 90 RMV

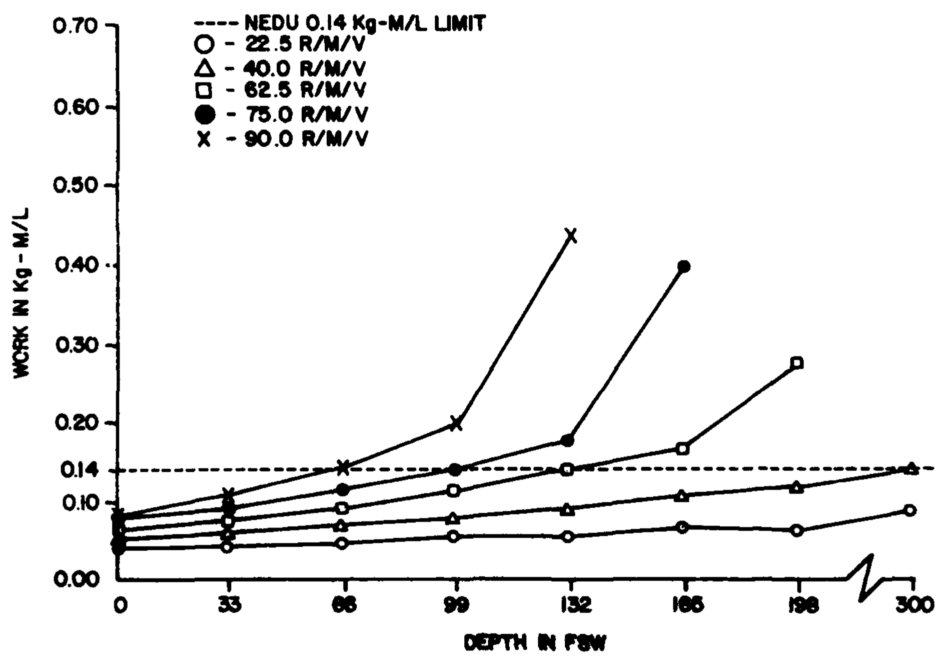

Figure 4A-6. Poseidon Cyclon 300
Breathing work vs. depth at 1000 psig supply pressure

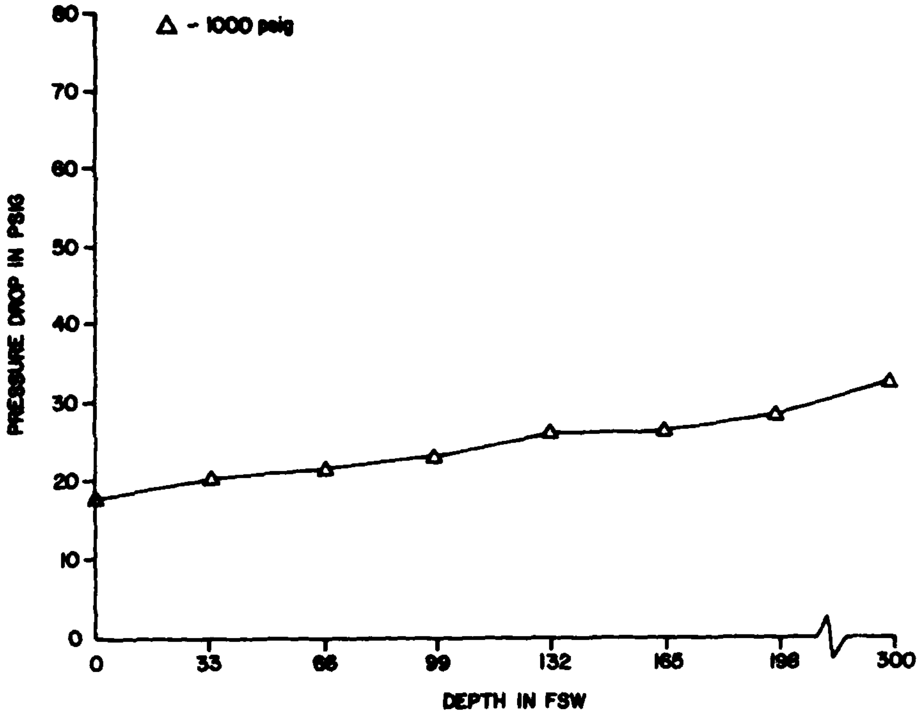

Figure 4A-7. Poseidon Cyclon 300
First stage pressure drop vs. depth at 22.5 RMV

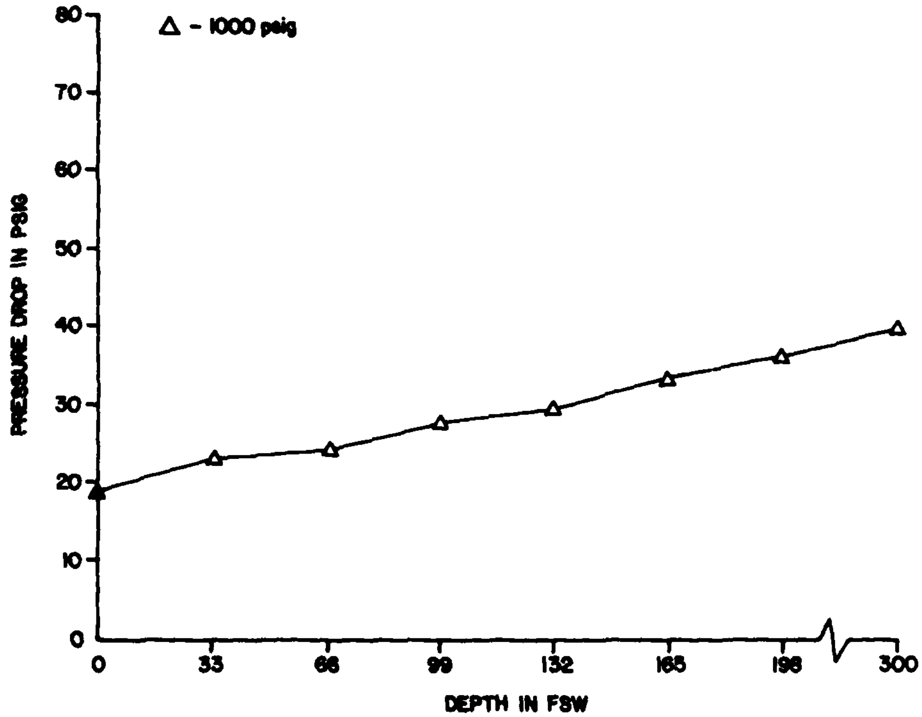

Figure 4A-8. Poseidon Cyclon 300
First stage pressure drop vs. depth at 40 RMV

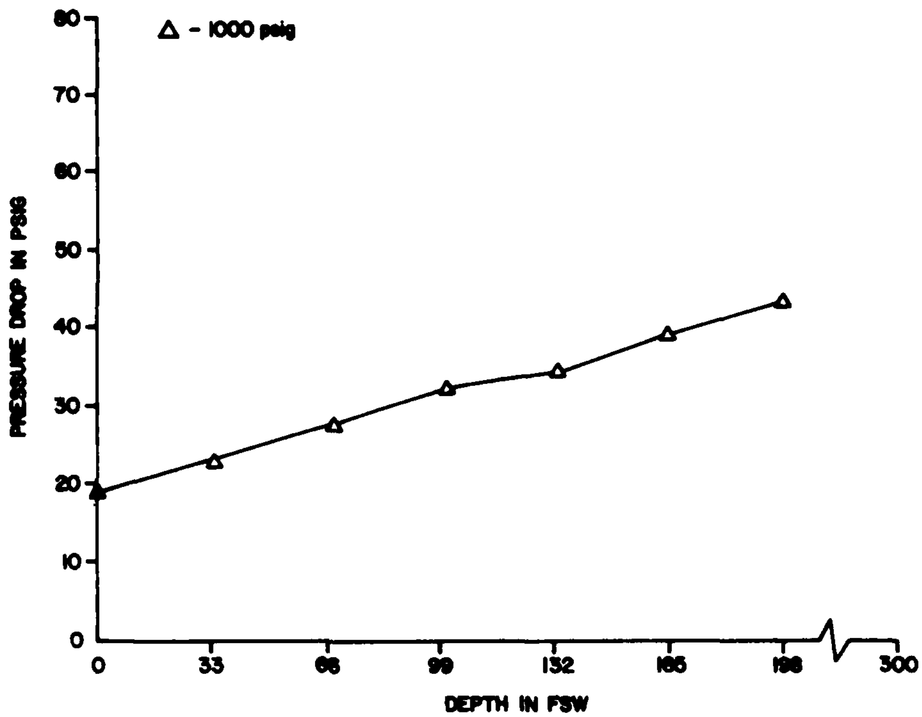

Figure 4A-9. Poseidon Cyclon 300
First stage pressure drop vs. depth at 62.5 RMV

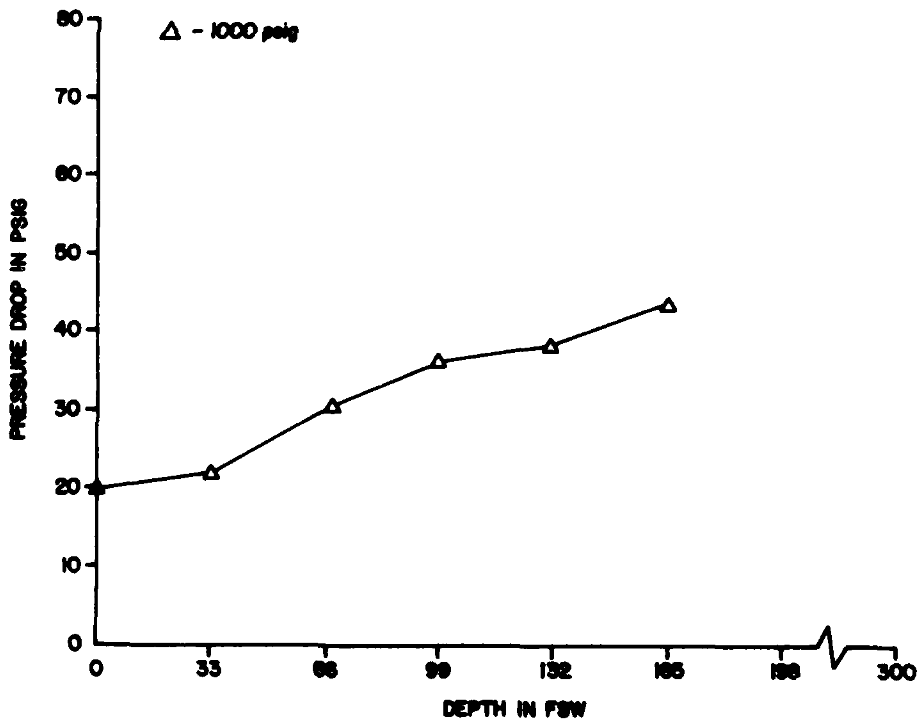

Figure 4A-10. Poseidon Cyclon 300
First stage pressure drop vs. depth at 75 RMV

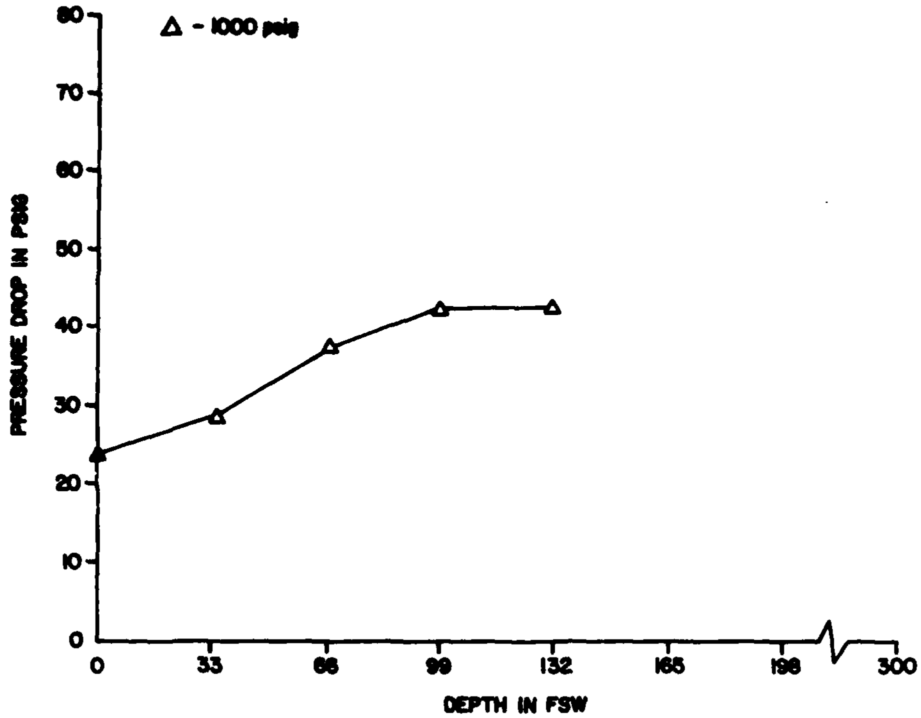

Figure 4A-11. Poseidon Cyclon 300
First stage pressure drop vs. depth at 90 RMV

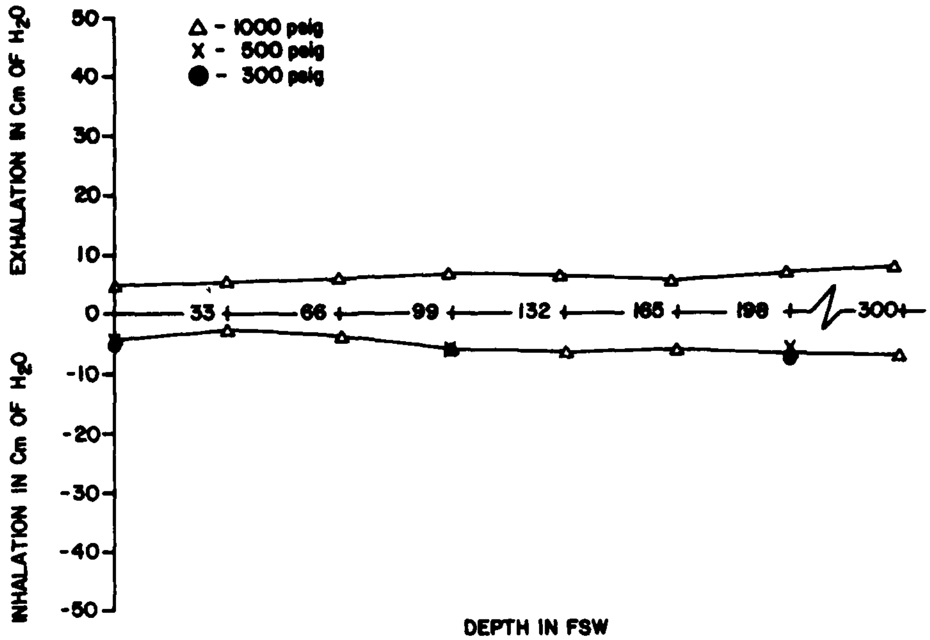

Figure 5A-1. Scubamaster Model 7687
Breathing resistance vs. depth at 22.5 RMV

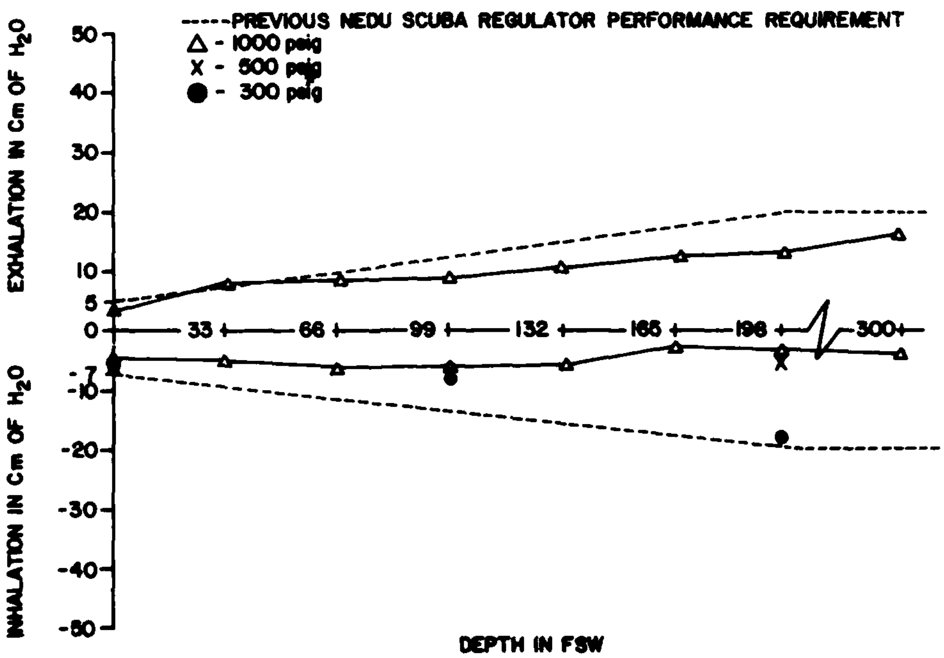

Figure 5A-2. Scubamaster Model 7687
Breathing resistance vs. depth at 40 RMV

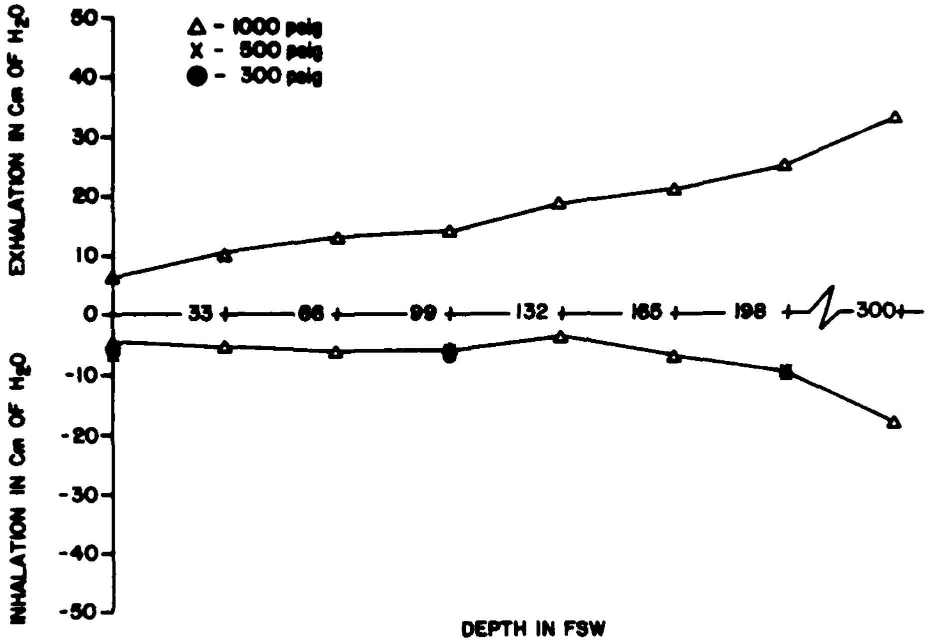

Figure 5A-3. Scubamaster Model 7687
Breathing resistance vs. depth at 62.5 RMV

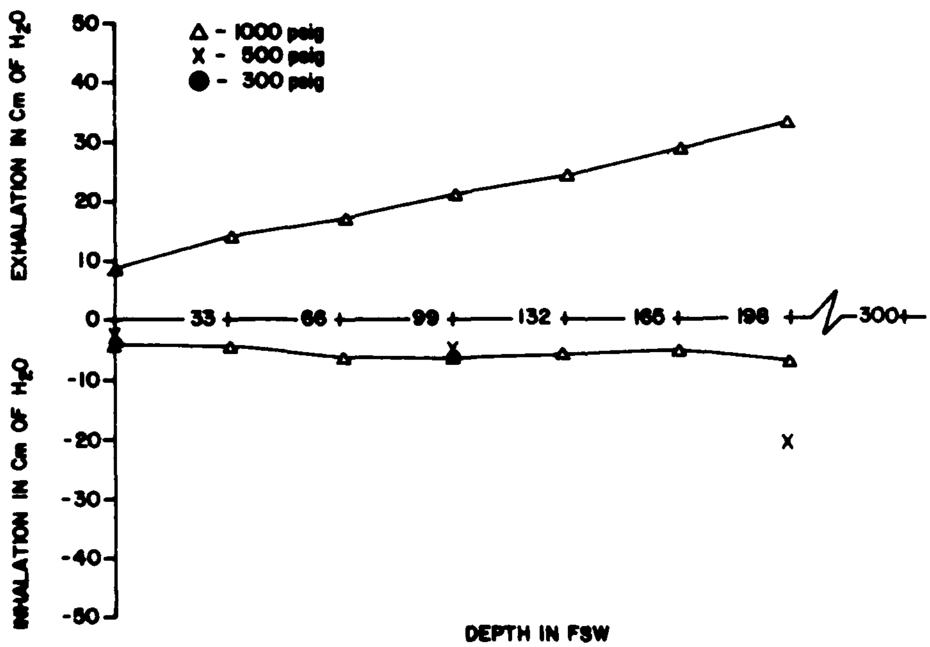

Figure 5A-4. Scubamaster Model 7687
Breathing resistance vs. depth at 75 RMV

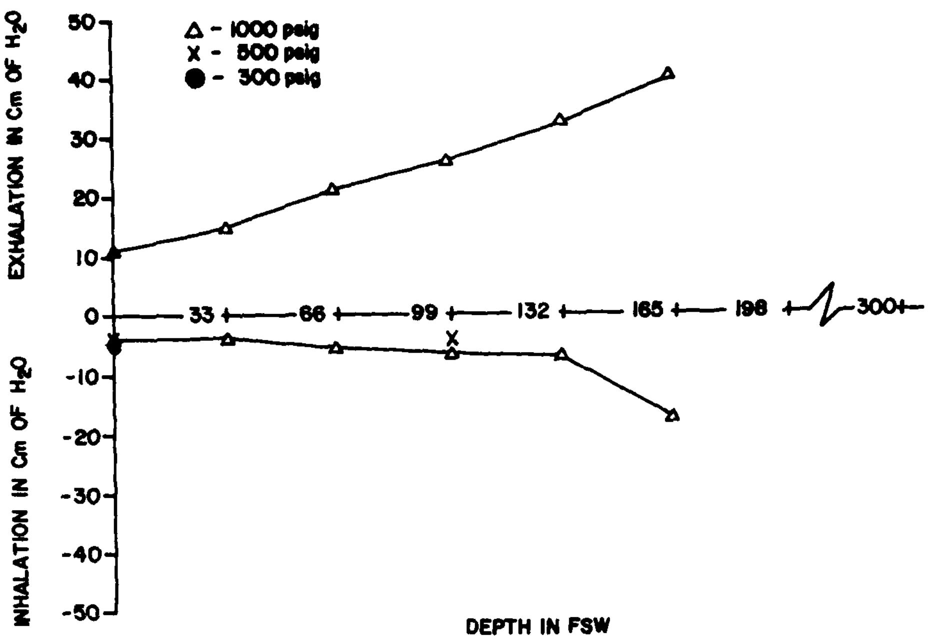

Figure 5A-5. Scubamaster Model 7687
Breathing resistance vs. depth at 90 RMV

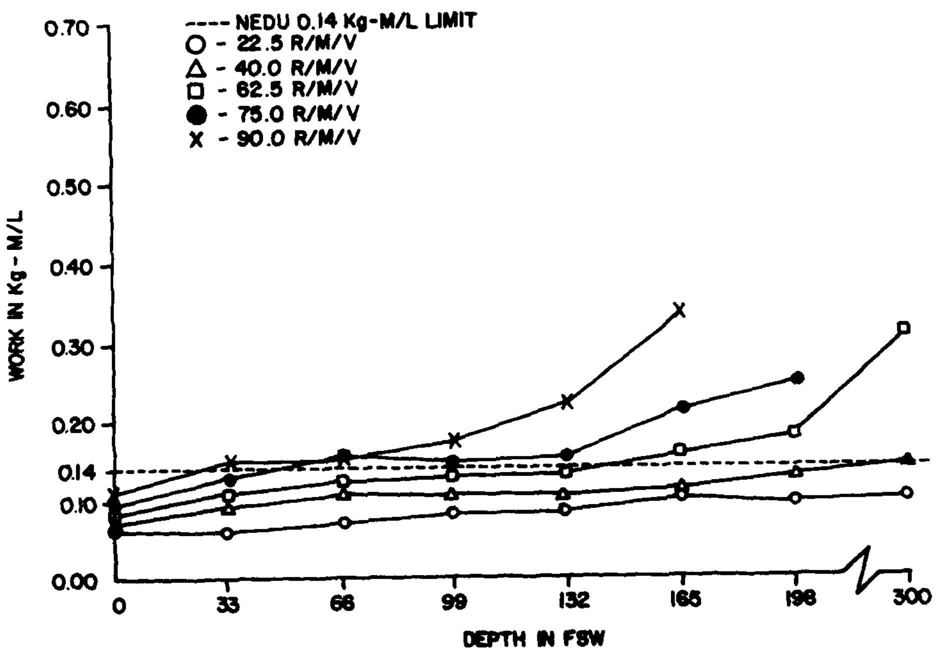

Figure 5A-6. Scubamaster Model 7687
Breathing work vs. depth at 1000 psig supply pressure

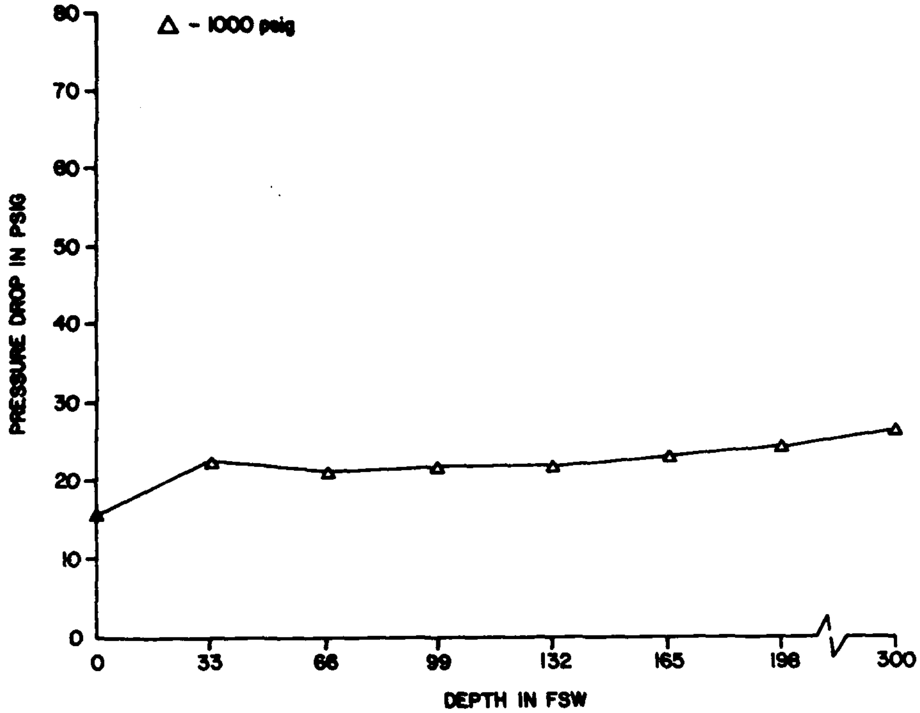

Figure 5A-7. Scubamaster Model 7687
First stage pressure drop vs. depth at 22.5 RMV

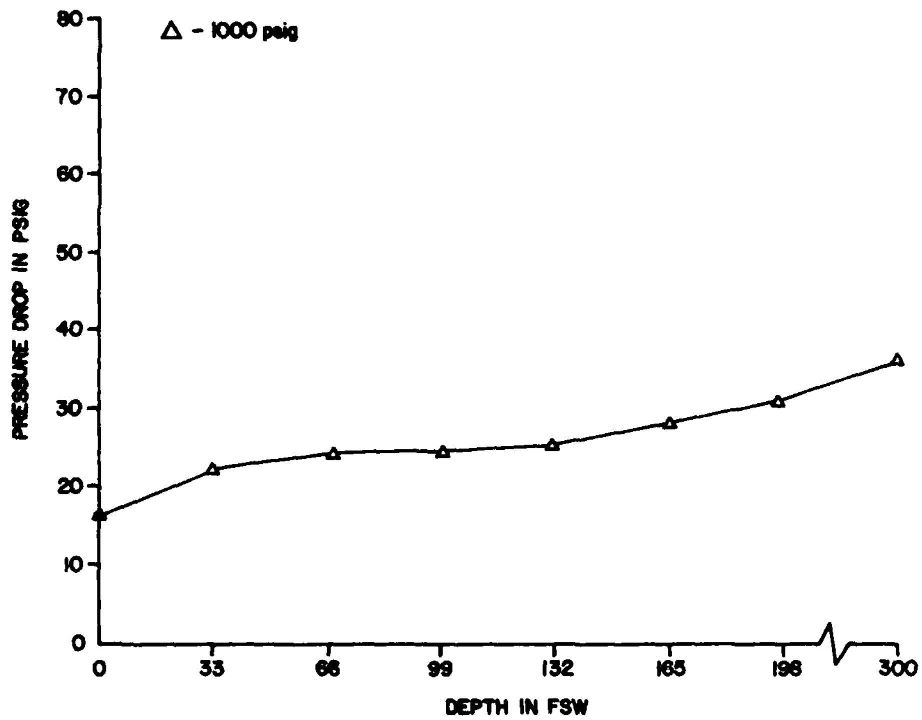

Figure 5A-8. Scubamaster Model 7687
First stage pressure drop vs. depth at 40 RMV

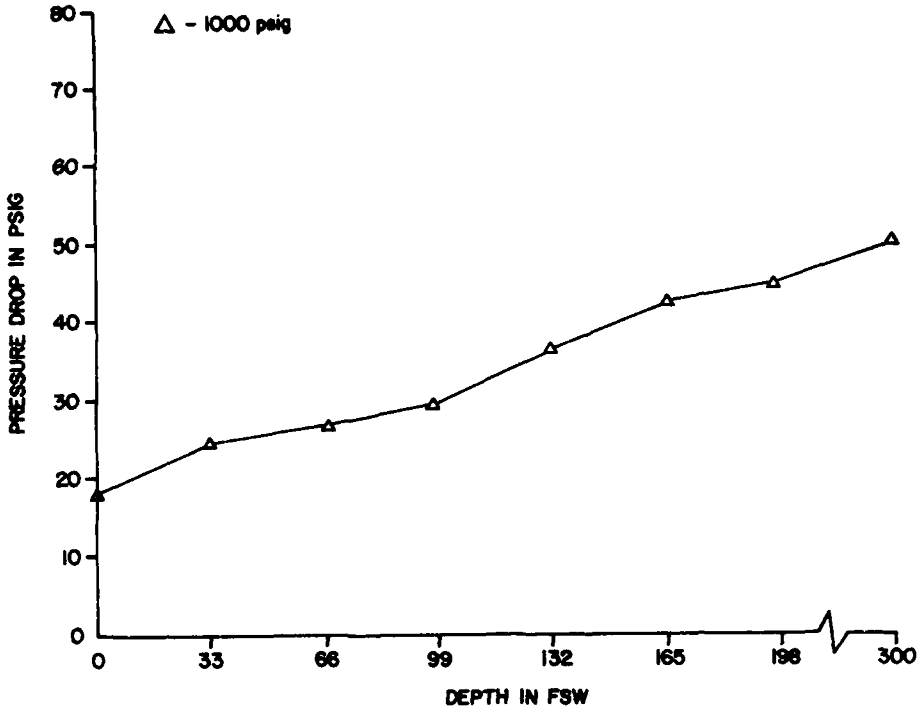

Figure 5A-9. Scubamaster Model 7687
First stage pressure drop vs. depth at 62.5 RMV

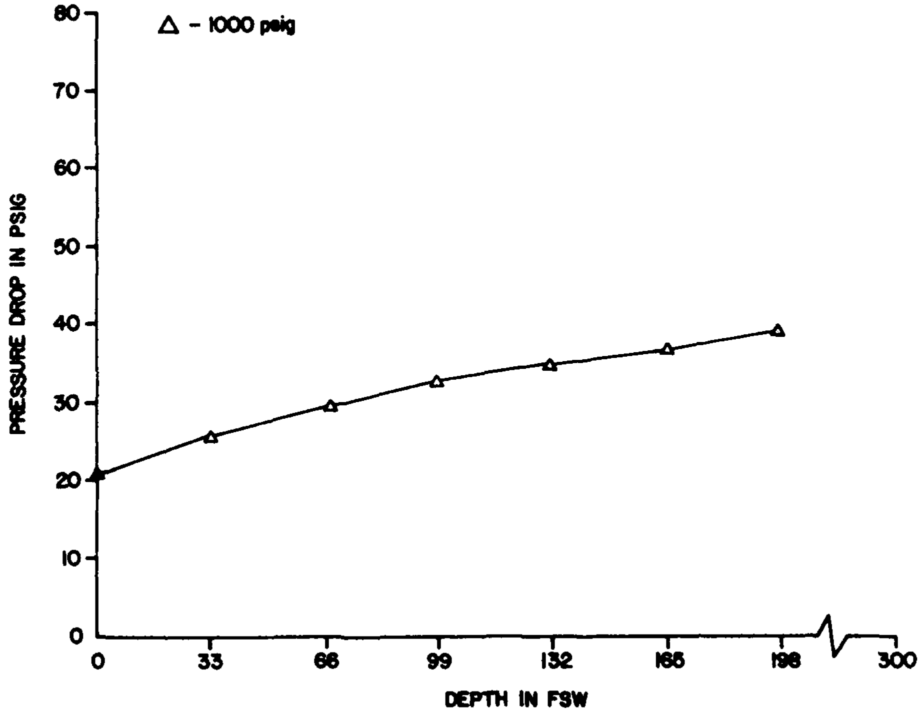

Figure 5A-10. Scubamaster Model 7687
First stage pressure drop vs. depth at 75 RMV

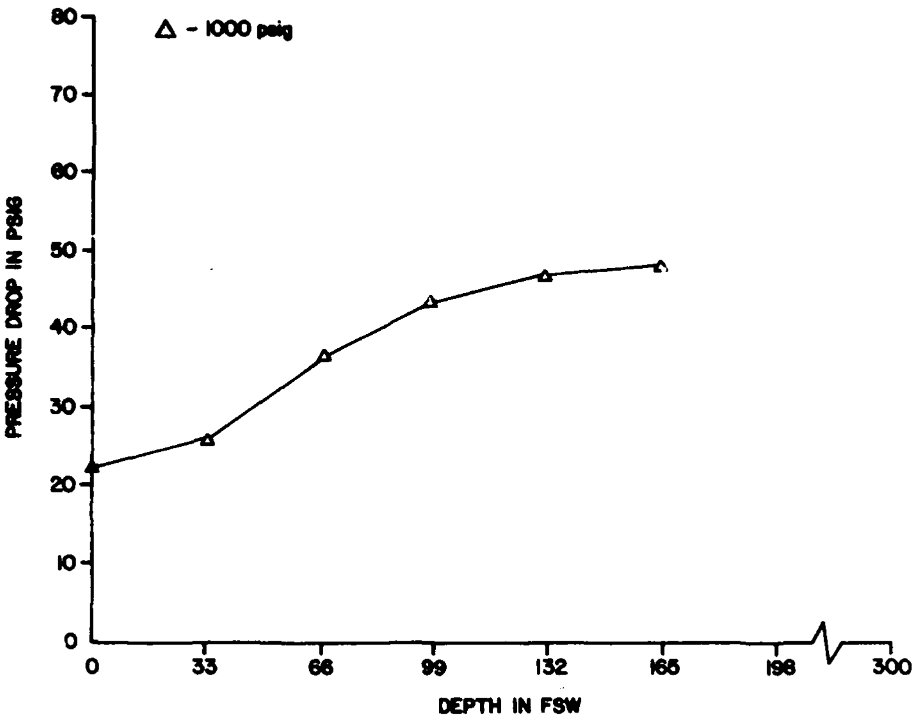

Figure 5A-11. Scubamaster Model 7687
First stage pressure drop vs. depth at 90 RMV

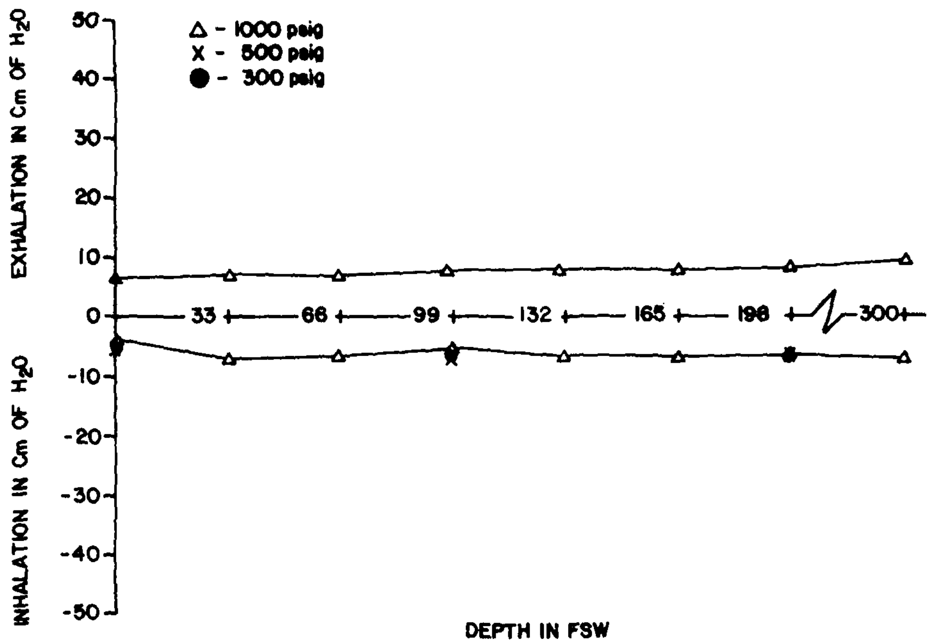

Figure 6A-1. Scubapro Mk V (4-Port Swivel)
Breathing resistance vs. depth at 22.5 RMV

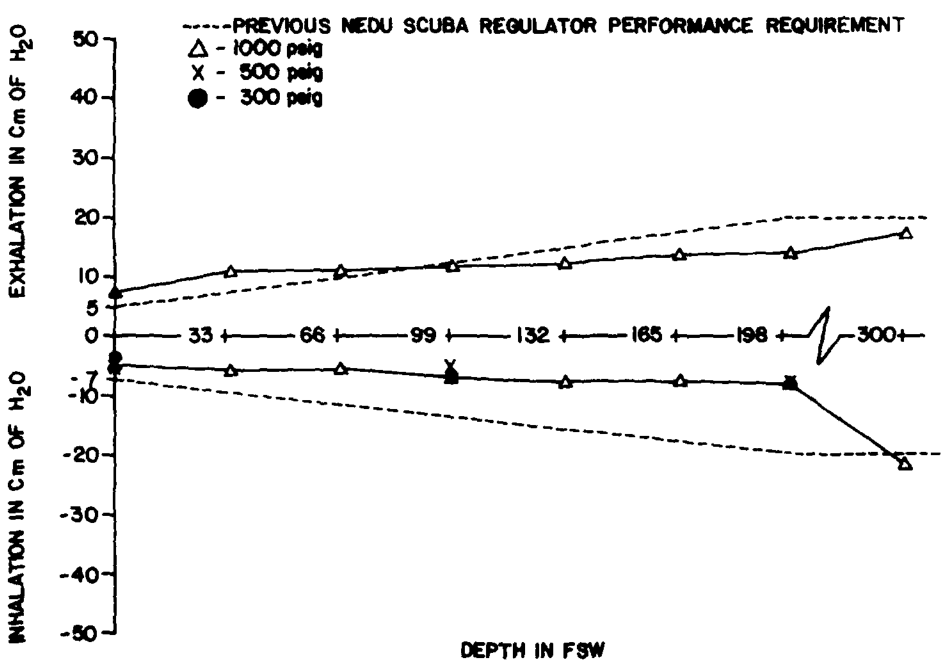

Figure 6A-2. Scubapro Mk V (4-Port Swivel)
Breathing resistance vs. depth at 40 RMV

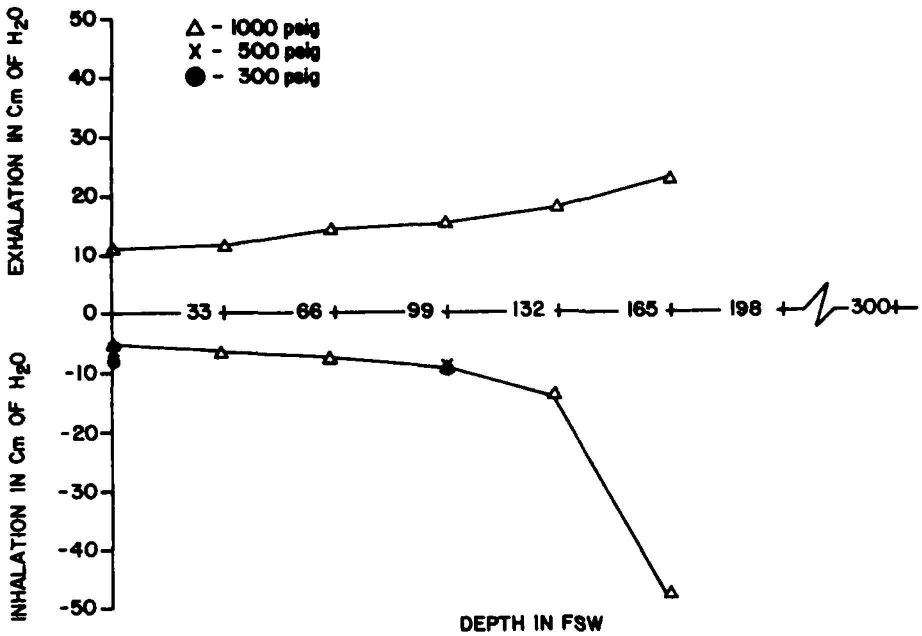

Figure 6A-3. Scubapro Mk V (4-Port Swivel)
Breathing resistance vs. depth at 62.5 RMV

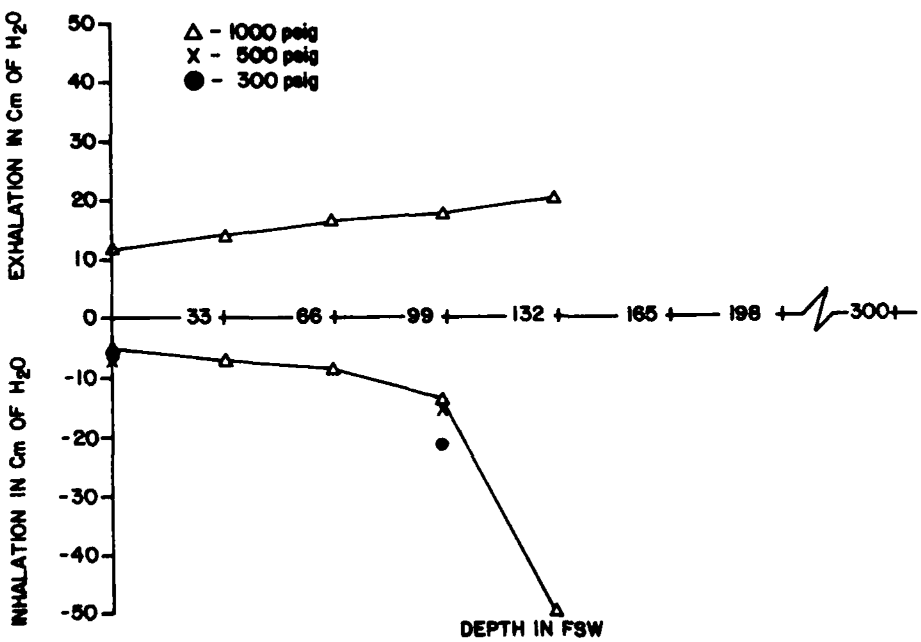

Figure 6A-4. Scubapro Mk V (4-Port Swivel)
Breathing resistance vs. depth at 75 RMV

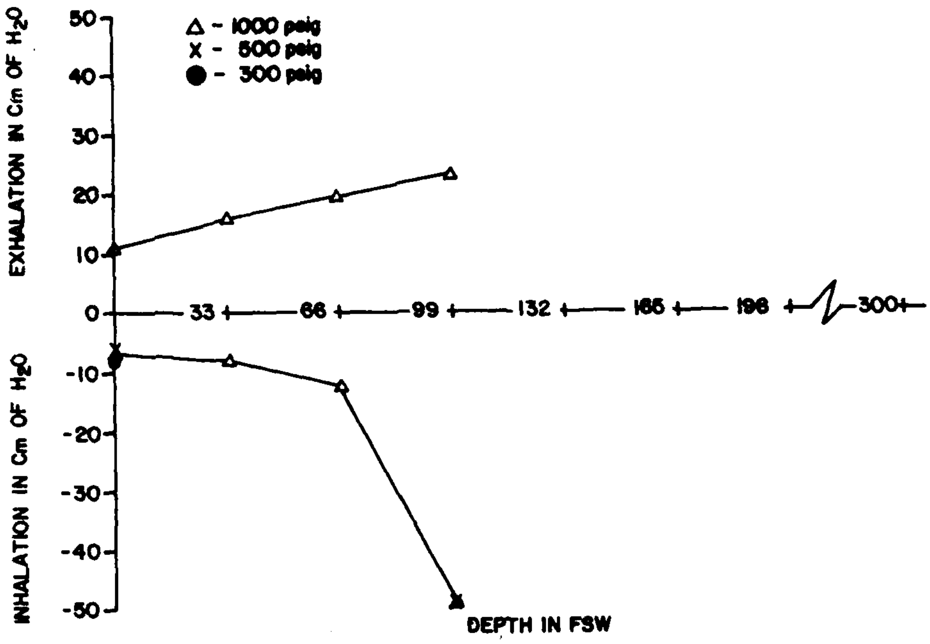

Figure 6A-5. Scubapro Mk V (4-Port Swivel)
Breathing resistance vs. depth at 90 RMV

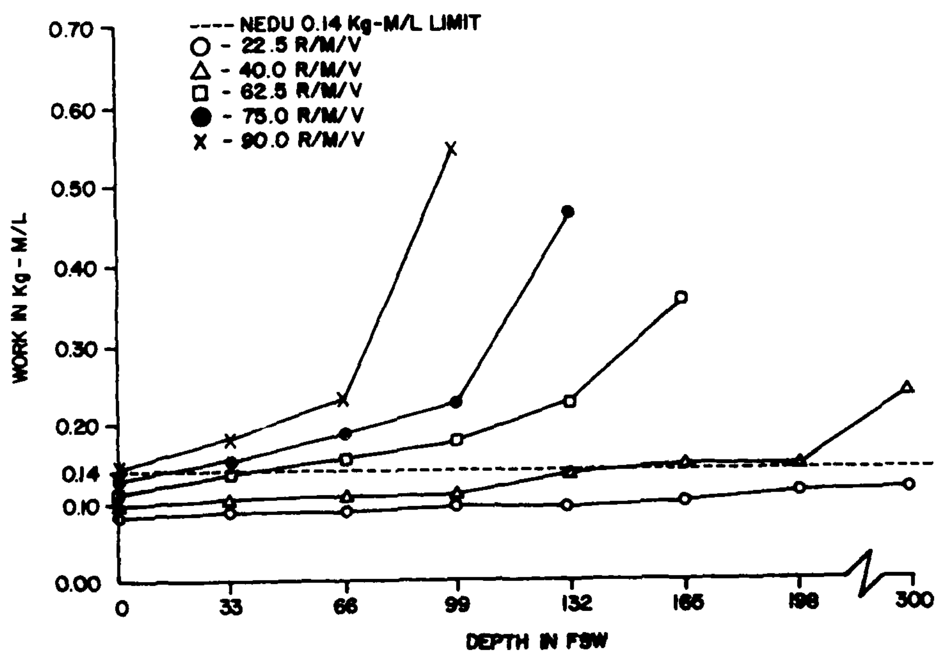

Figure 6A-6. Scubapro Mk V (4-Port Swivel)
Breathing work vs. depth at 1000 psig supply pressure

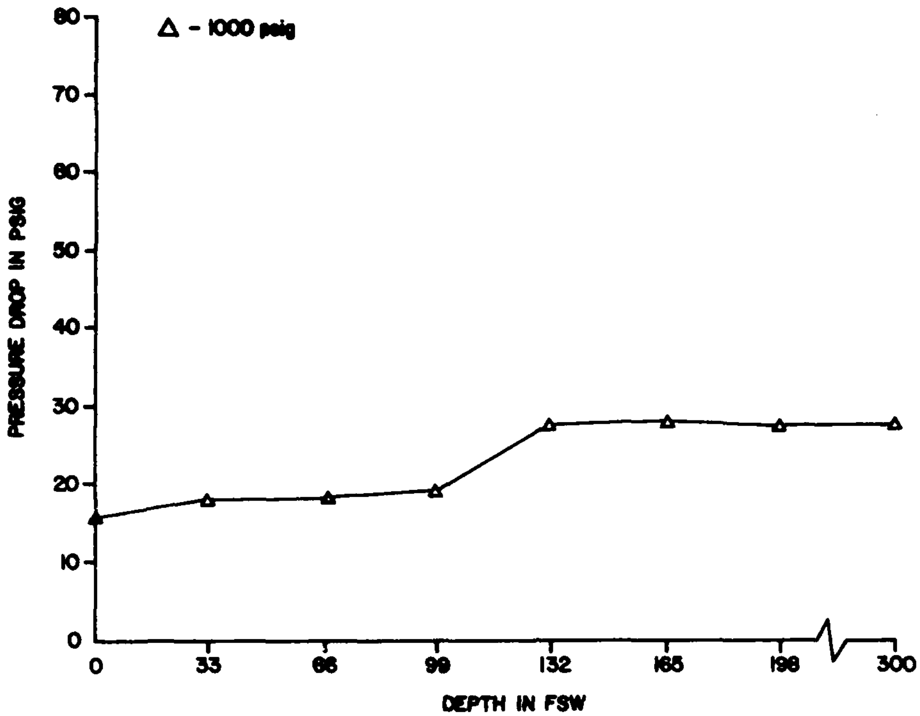

Figure 6A-7. Scubapro Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 22.5 RMV

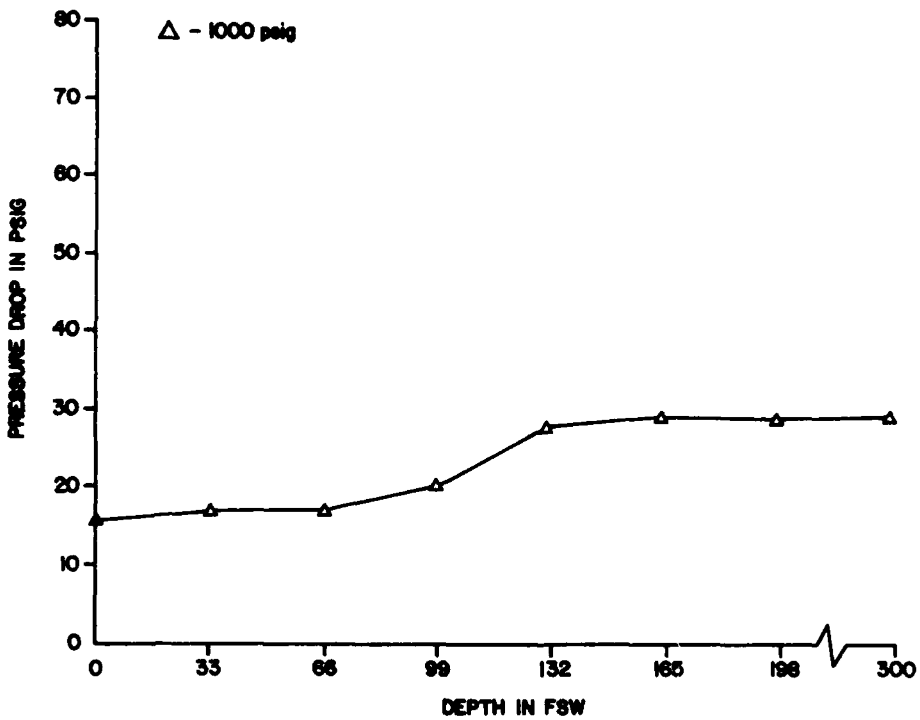

Figure 6A-8. Scubapro Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 40 RMV

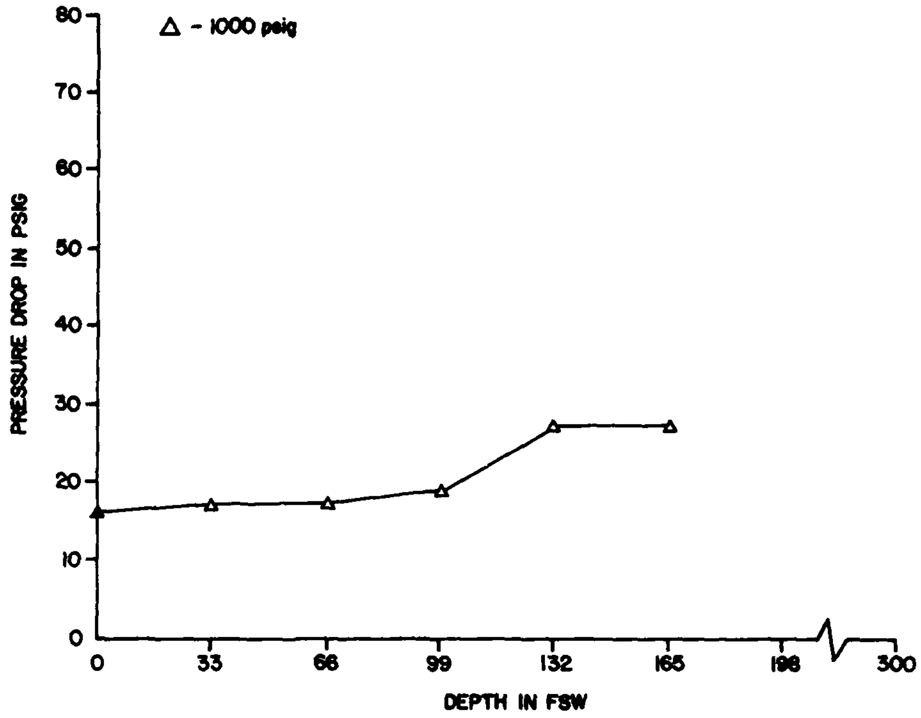

Figure 6A-9. Scubapro Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 62.5 RMV

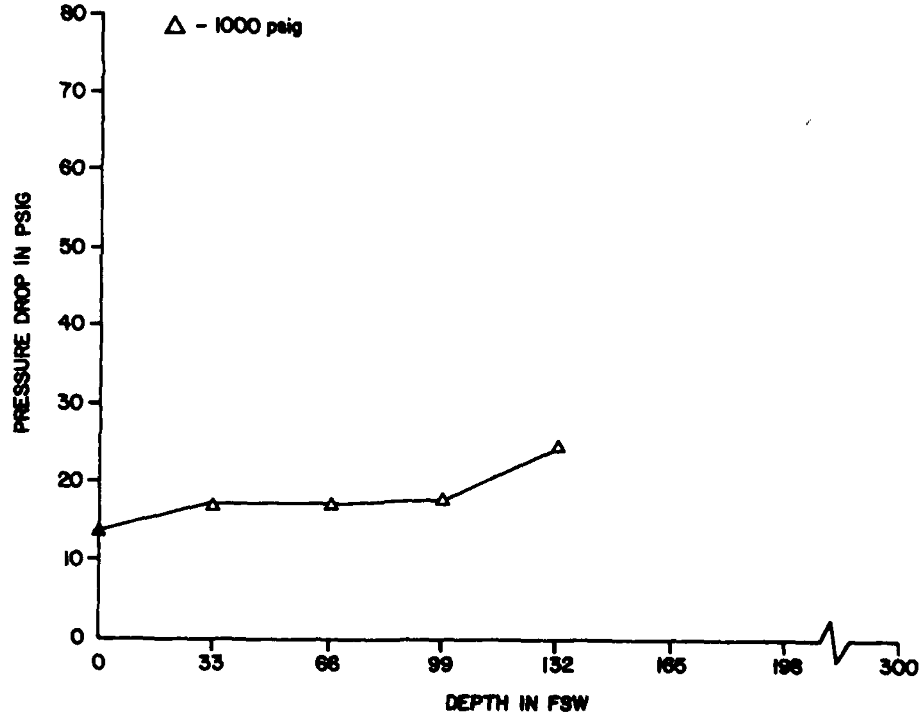

Figure 6A-10. Scubapro Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 75 RMV

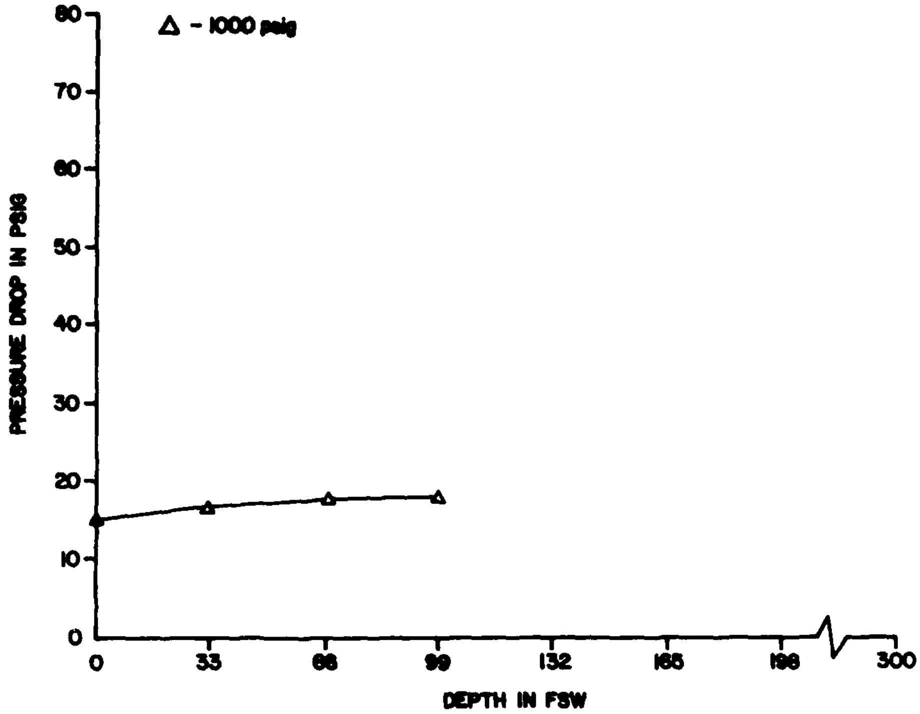

Figure 6A-11. Scubapro Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 90 RMV

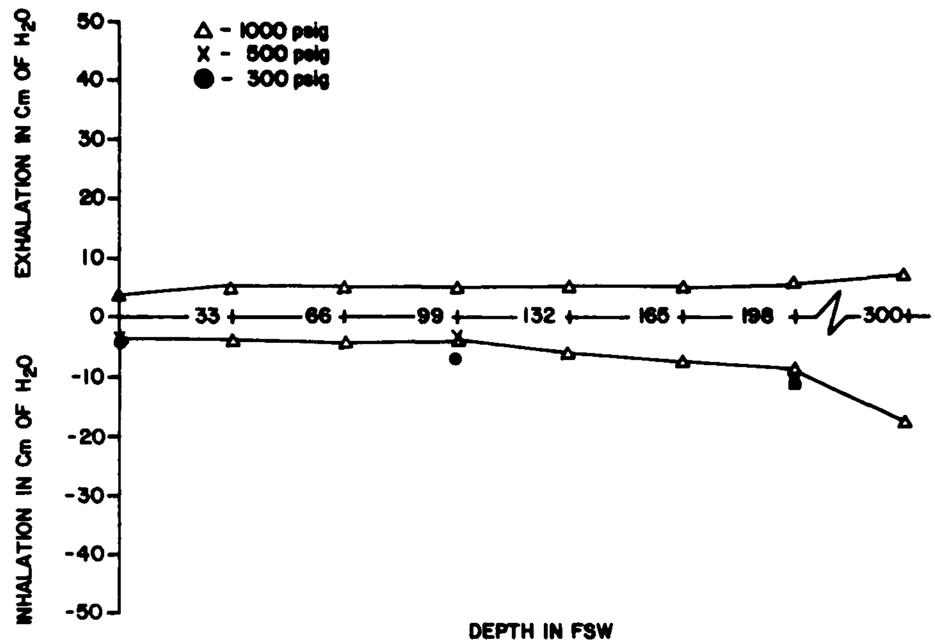

Figure 6B-1. Scubapro Pilot Mk V (4-Port Swivel)
Breathing resistance vs. depth at 22.5 RMV

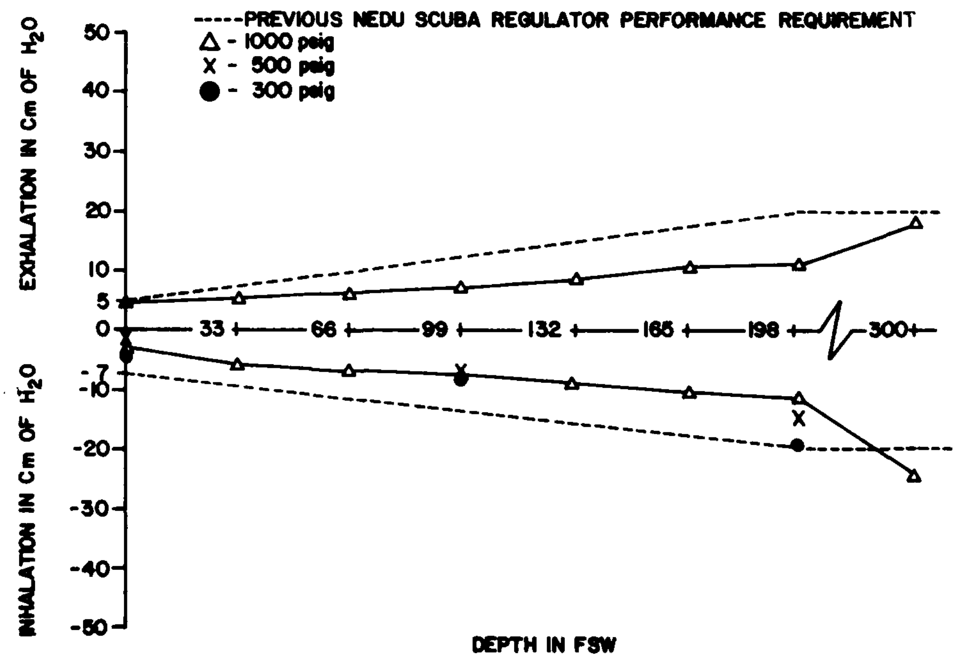

Figure 6B-2. Scubapro Pilot Mk V (4-Port Swivel)
Breathing resistance vs. depth at 40 RMV

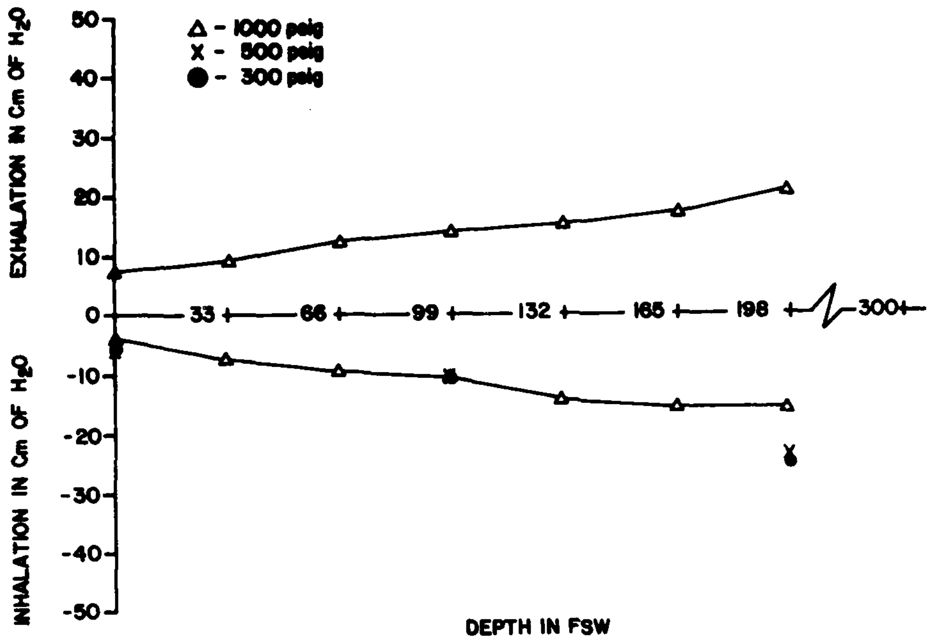

Figure 6B-3. Scubapro Pilot Mk V (4-Port Swivel)
Breathing resistance vs. depth at 62.5 RMV

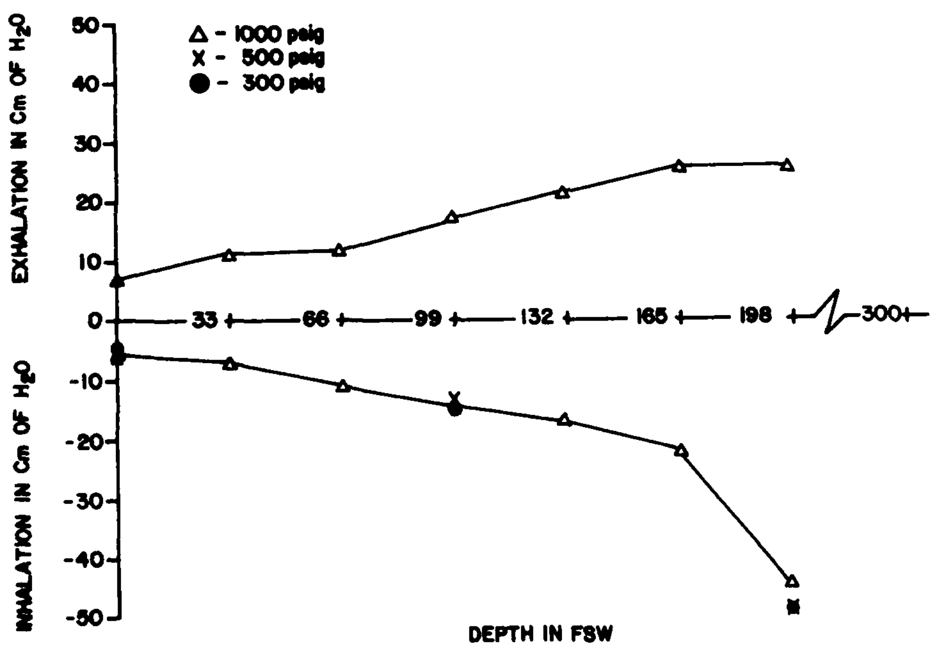

Figure 6B-4. Scubapro Pilot Mk V (4-Port Swivel)
Breathing resistance vs. depth at 75 RMV

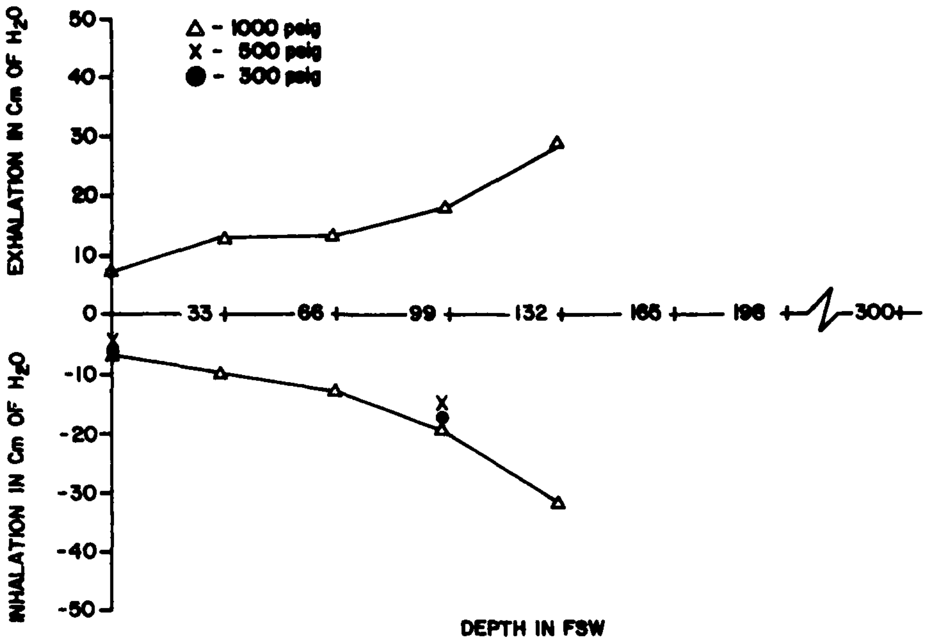

Figure 6B-5. Scubapro Pilot Mk V (4-Port Swivel)
Breathing resistance vs. depth at 90 RMV

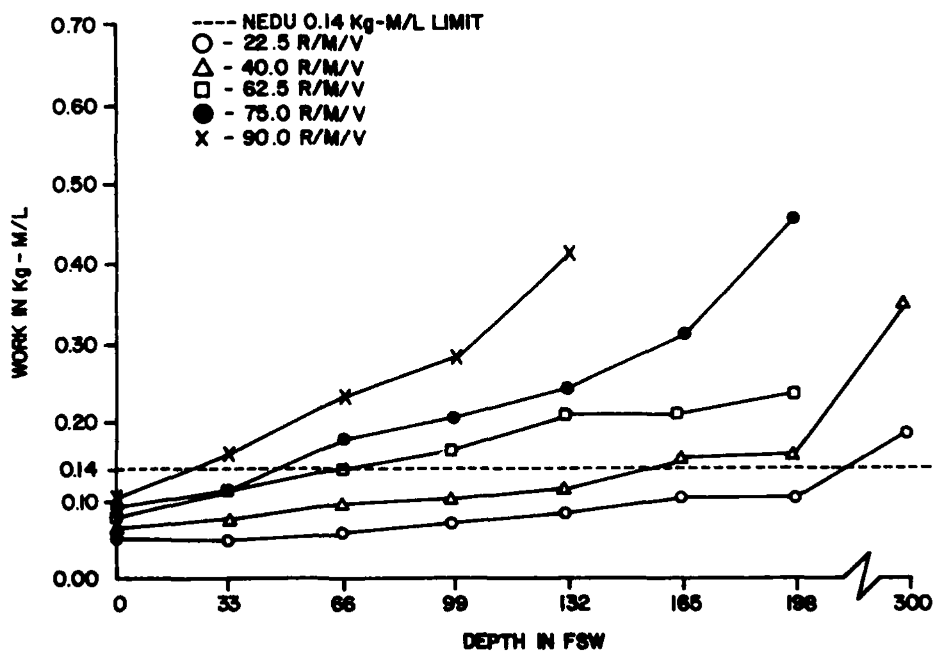

Figure 6B-6. Scubapro Pilot Mk V (4-Port Swivel)
Breathing work vs. depth at 1000 psig supply pressure

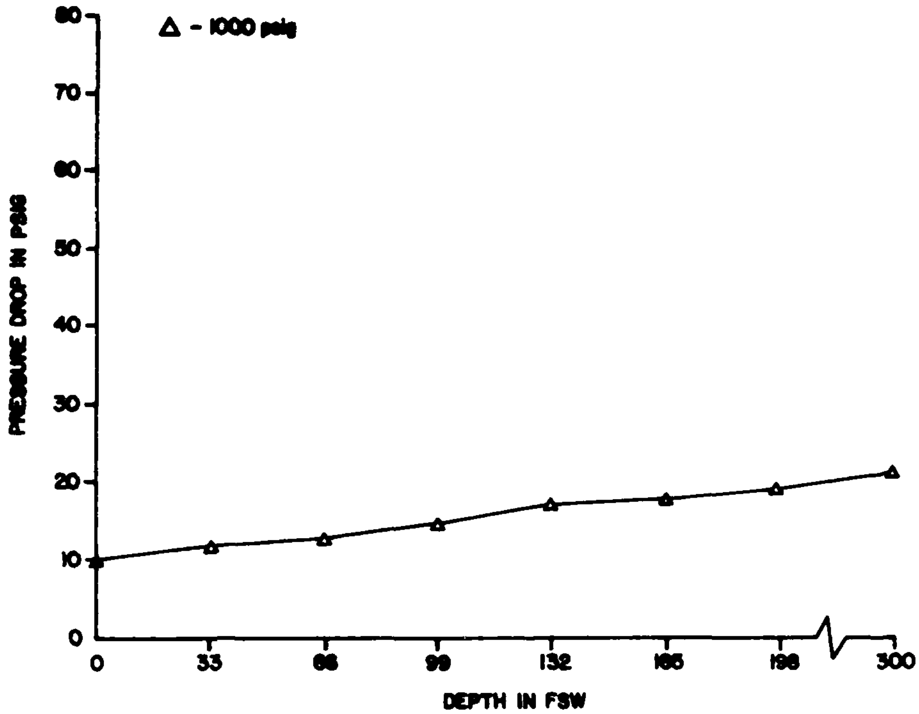

Figure 6B-7. Scubapro Pilot Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 22.5 RMV

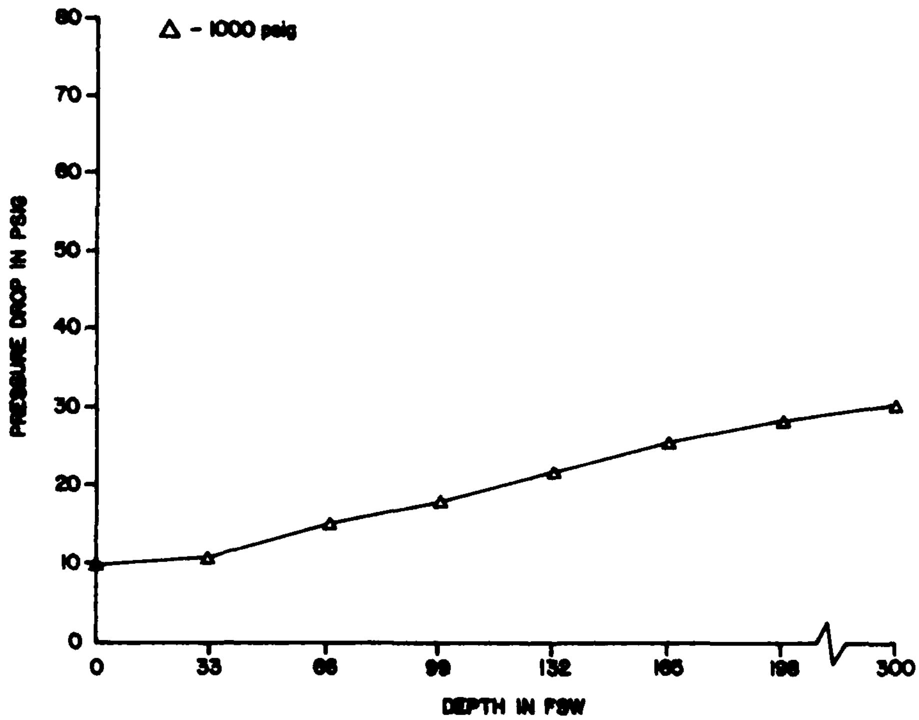

Figure 6B-8. Scubapro Pilot Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 40 RMV

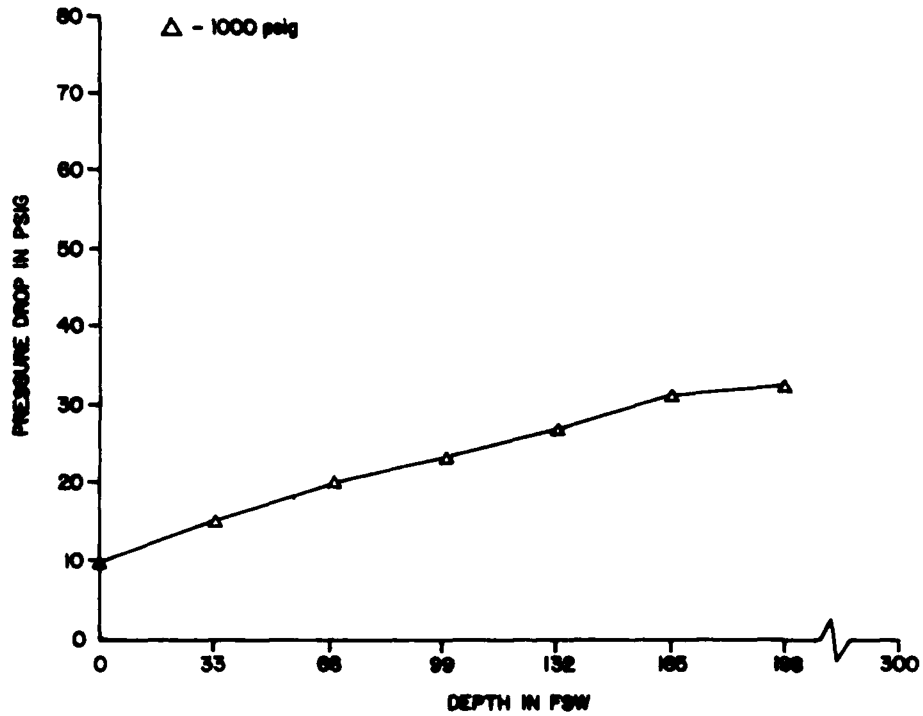

Figure 6B-9. Scubapro Pilot Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 62.5 RMV

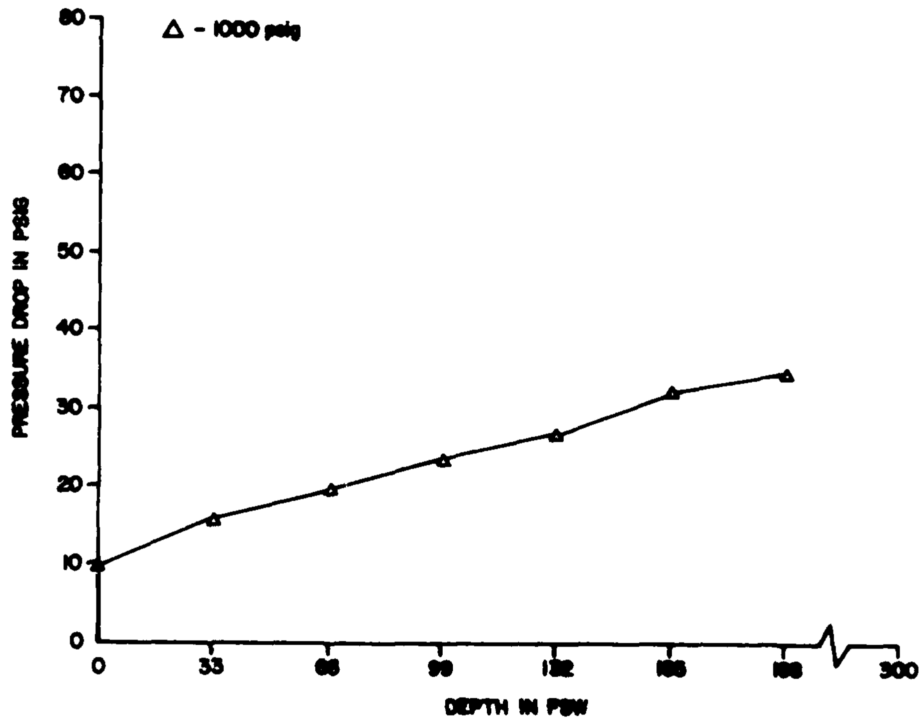

Figure 6B-10. Scubapro Pilot Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 75 RMV

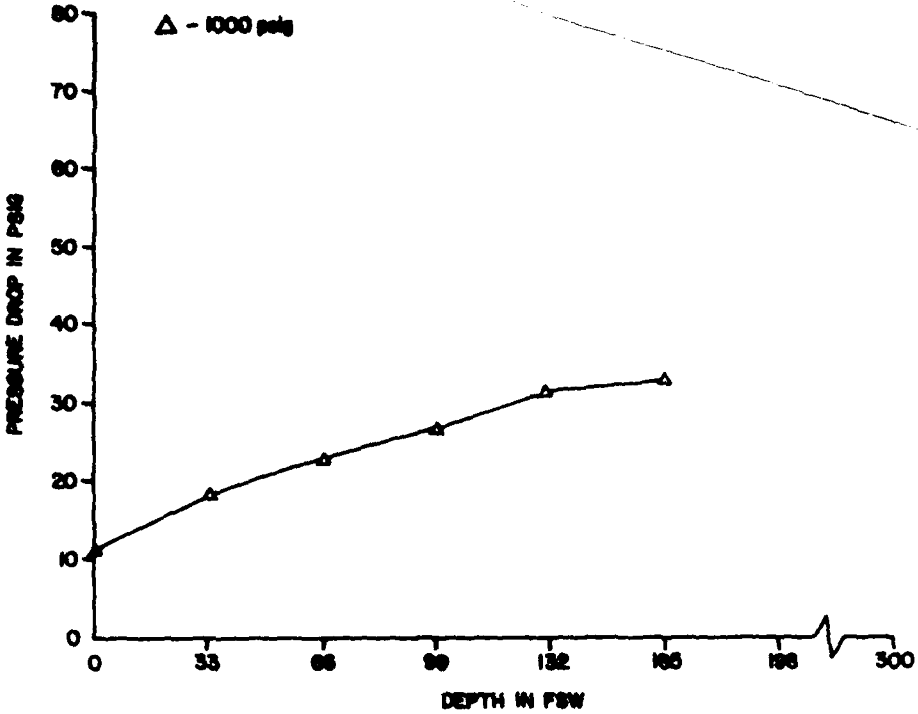

Figure 6B-11. Scubapro Pilot Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 90 RMV

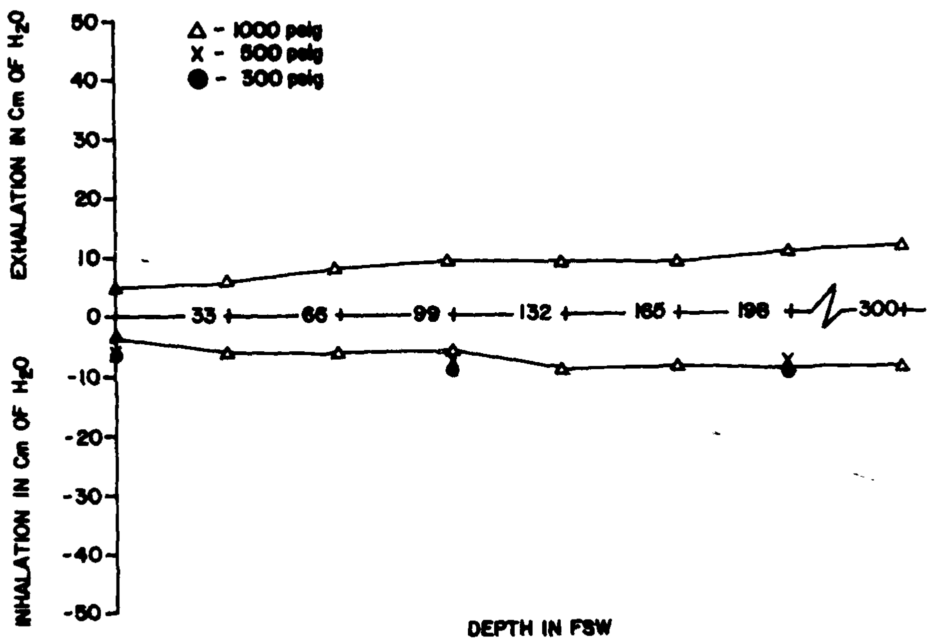

Figure 6C-1. Scubapro Mk V (5-Port Swivel)
Breathing resistance vs. depth at 22.5 RMV

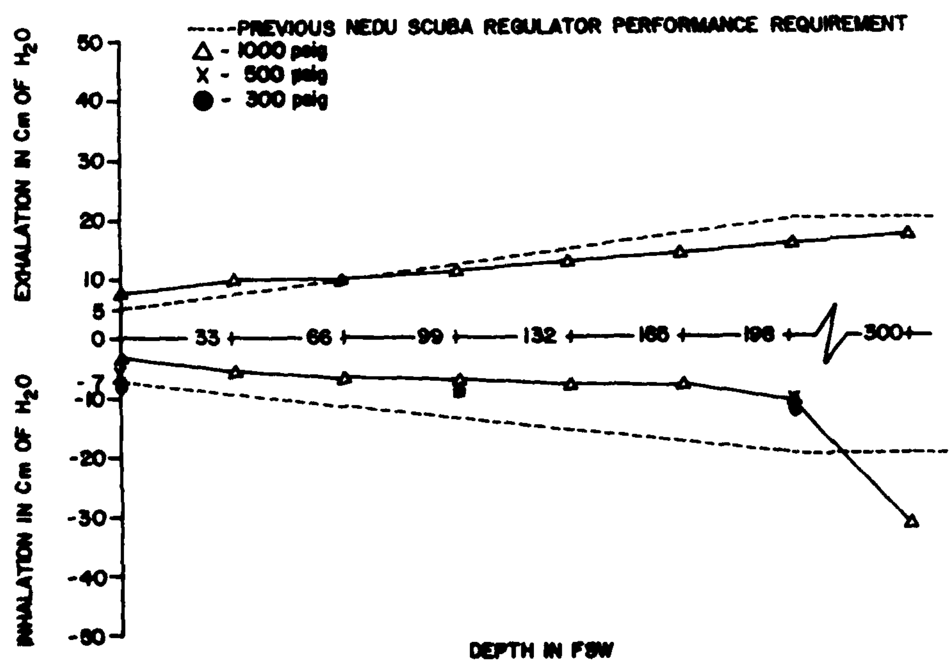

Figure 6C-2. Scubapro Mk V (5-Port Swivel)
Breathing resistance vs. depth at 40 RMV

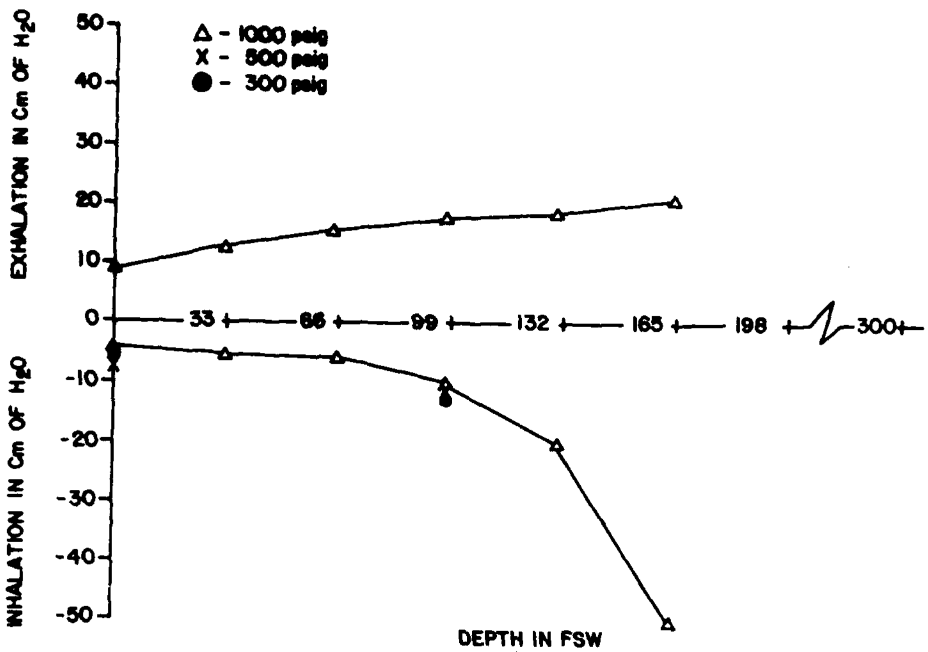

Figure 6C-3. Scubapro Mk V (5-Port Swivel)
Breathing resistance vs. depth at 62.5 RMV

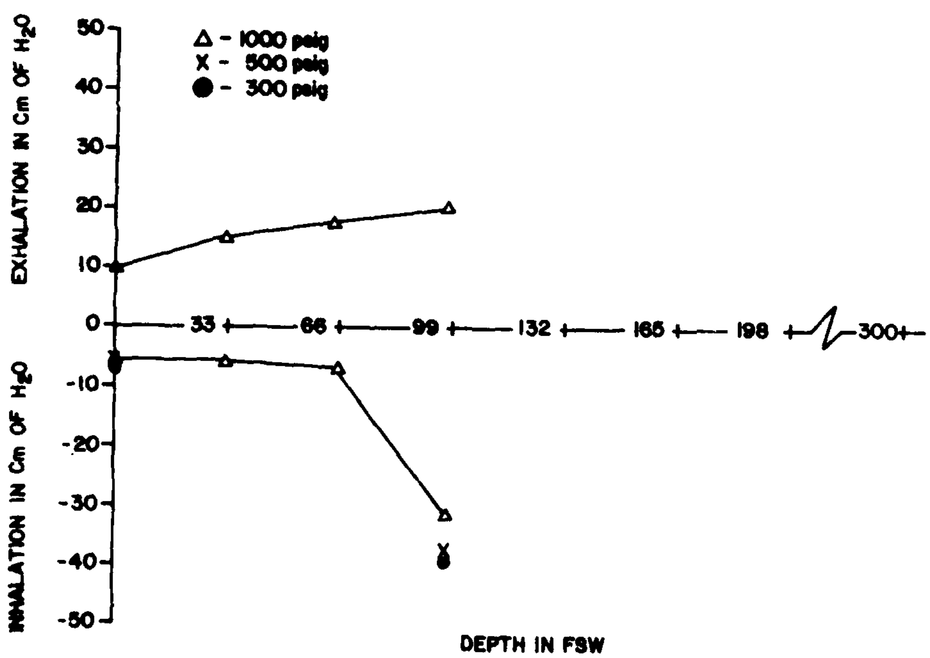

Figure 6C-4. Scubapro Mk V (5-Port Swivel)
Breathing resistance vs. depth at 75 RMV

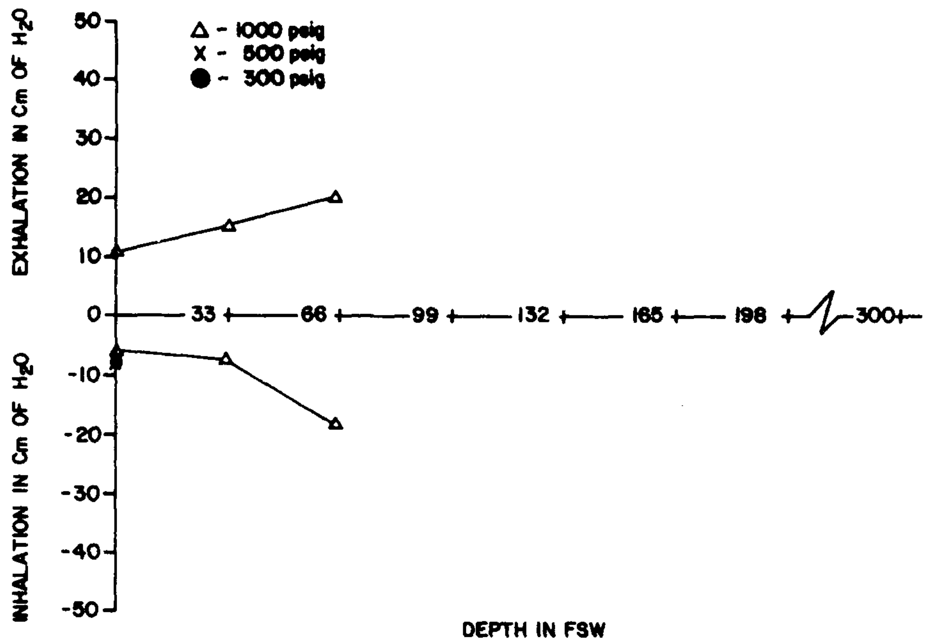

Figure 6C-5. Scubapro Mk V (5-Port Swivel)
Breathing resistance vs. depth at 90 RMV

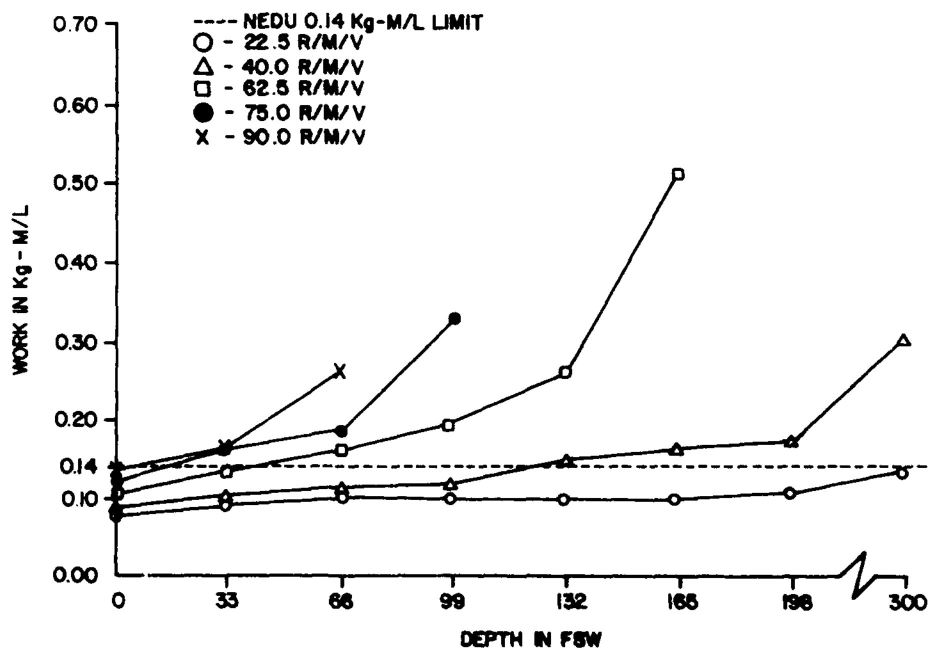

Figure 6C-6. Scubapro Mk V (5-Port Swivel)
Breathing work vs. depth at 1000 psig supply pressure

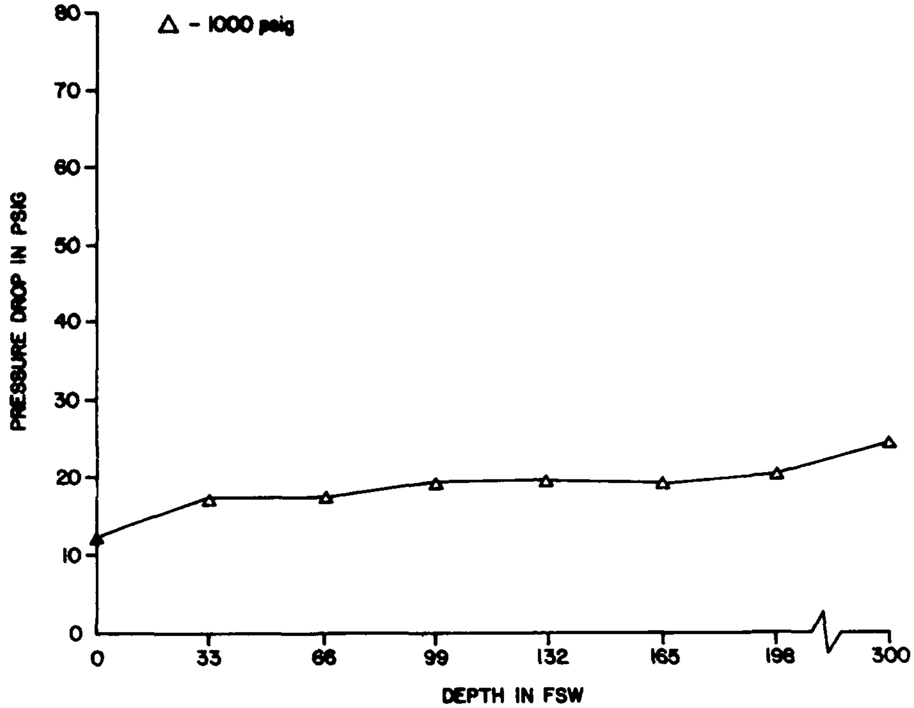

Figure 6C-7. Scubapro Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 22.5 RMV

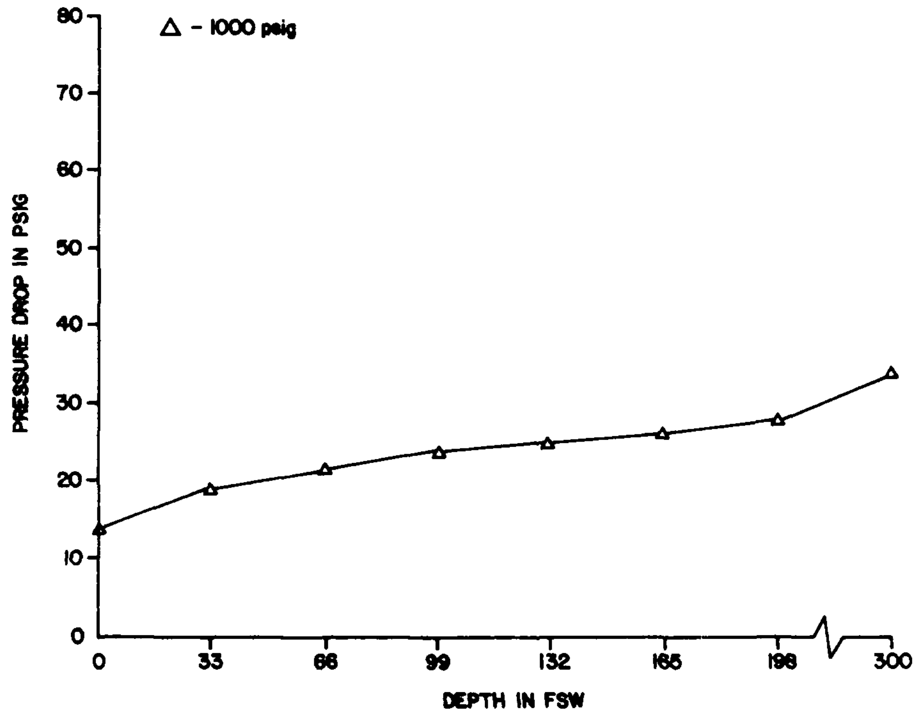

Figure 6C-8. Scubapro Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 40 RMV

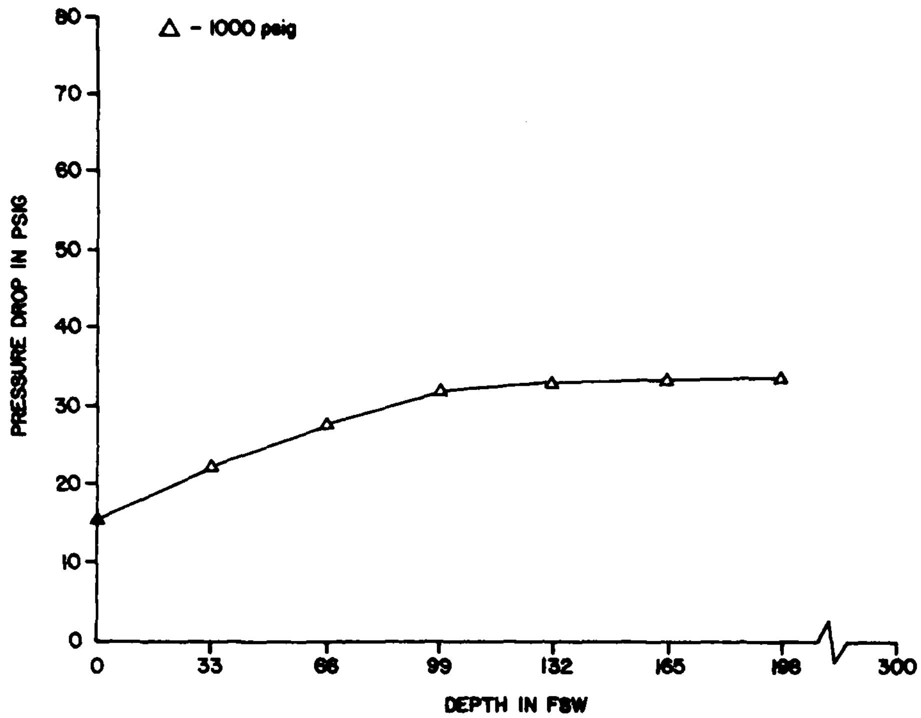

Figure 6C-9. Scubapro Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 62.5 RMV

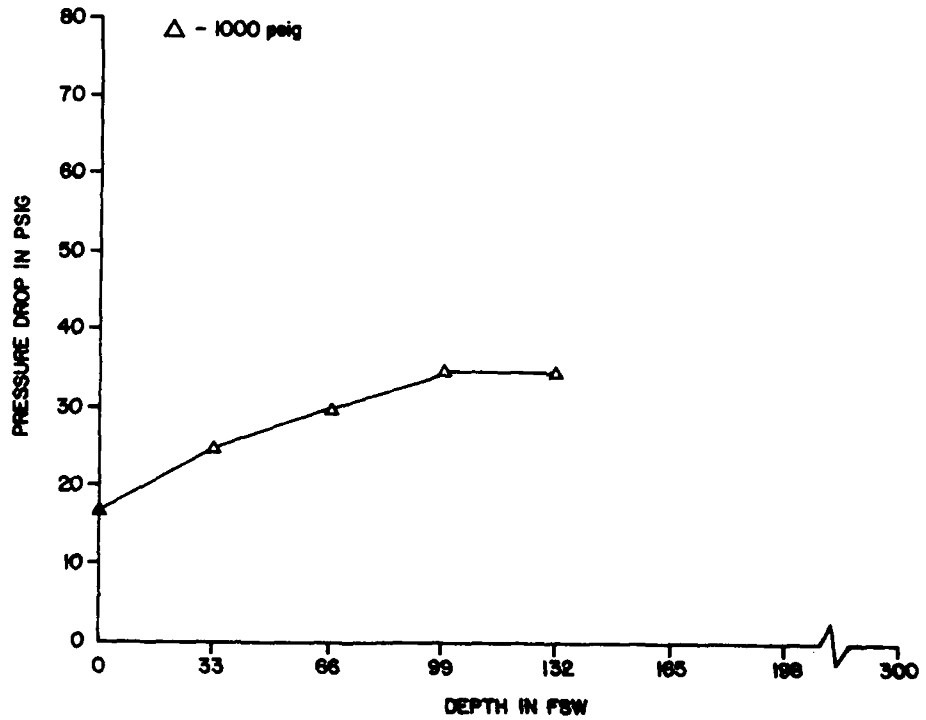

Figure 6C-10. Scubapro Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 75 RMV

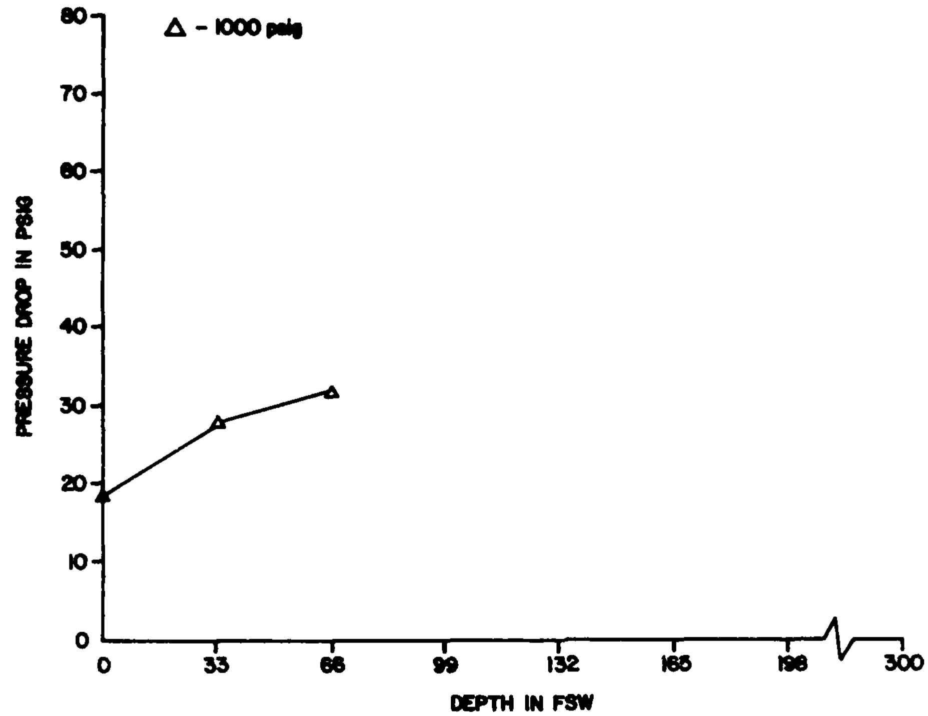

Figure 6C-11. Scubapro Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 90 RMV

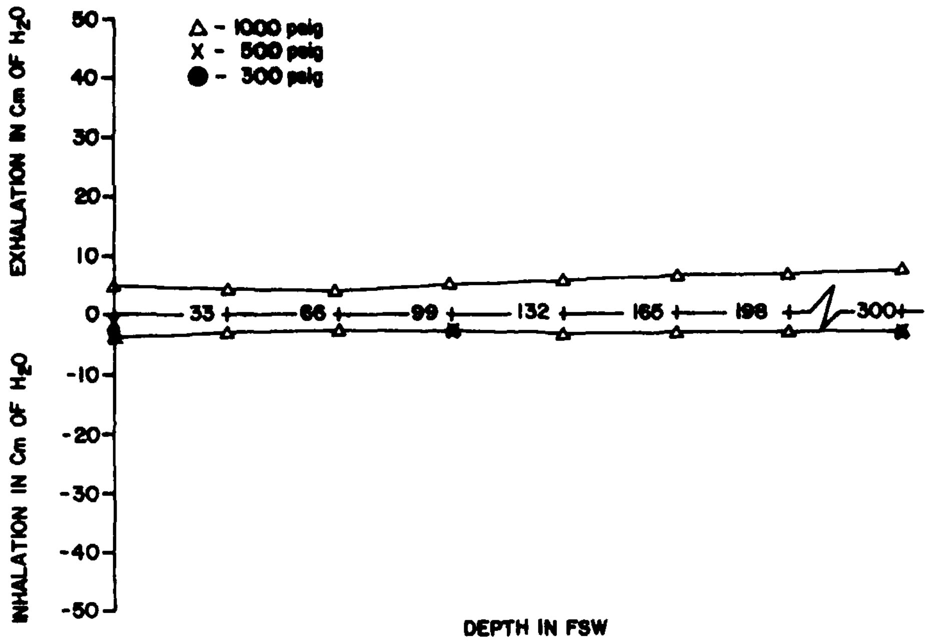

Figure 6D-1. Scubapro Air I/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 22.5 RMV

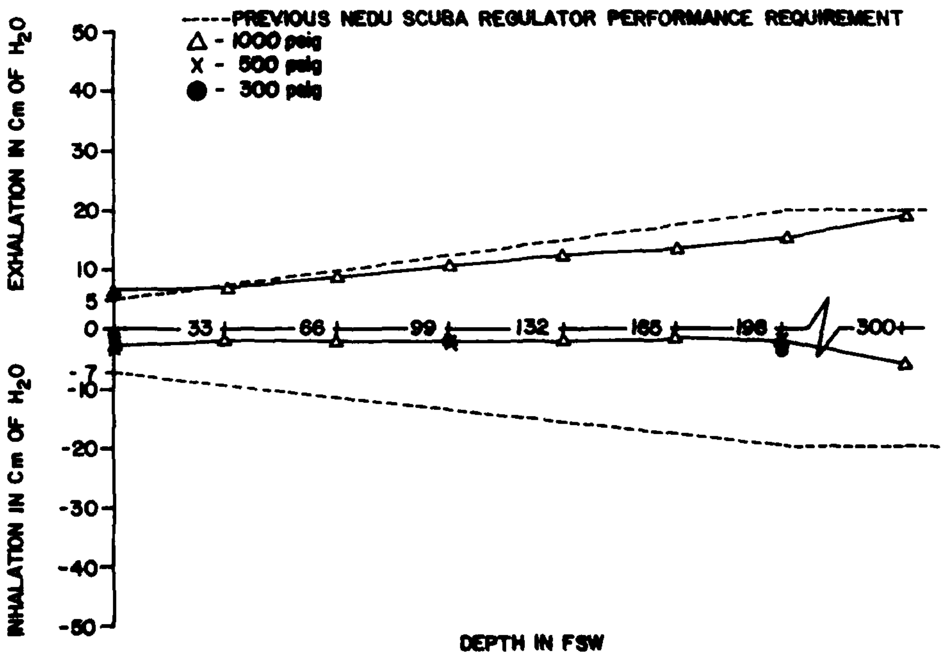

Figure 6D-2. Scubapro Air I/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 40 RMV

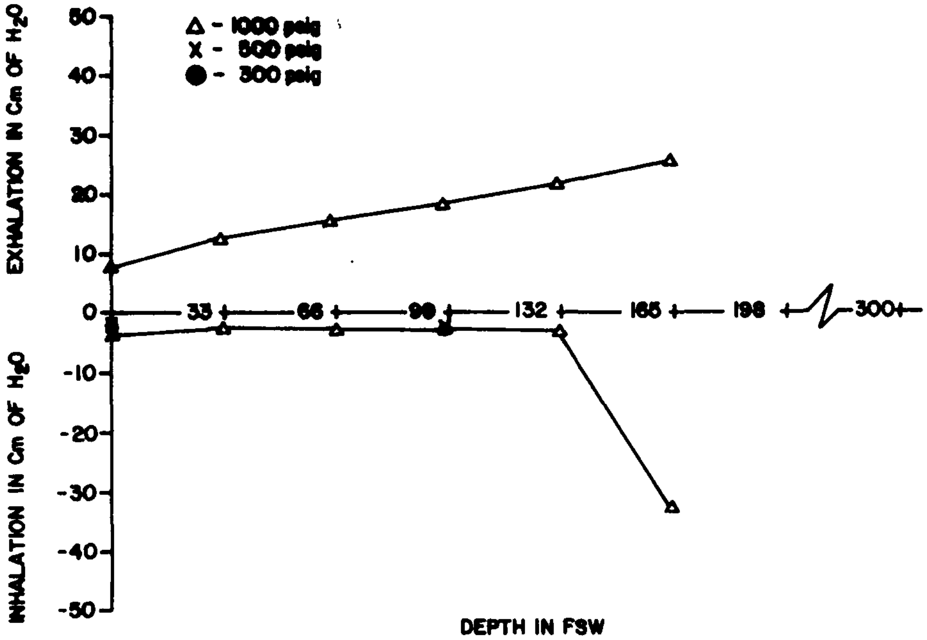

Figure 6D-3. Scubapro Air I/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 62.5 RMV

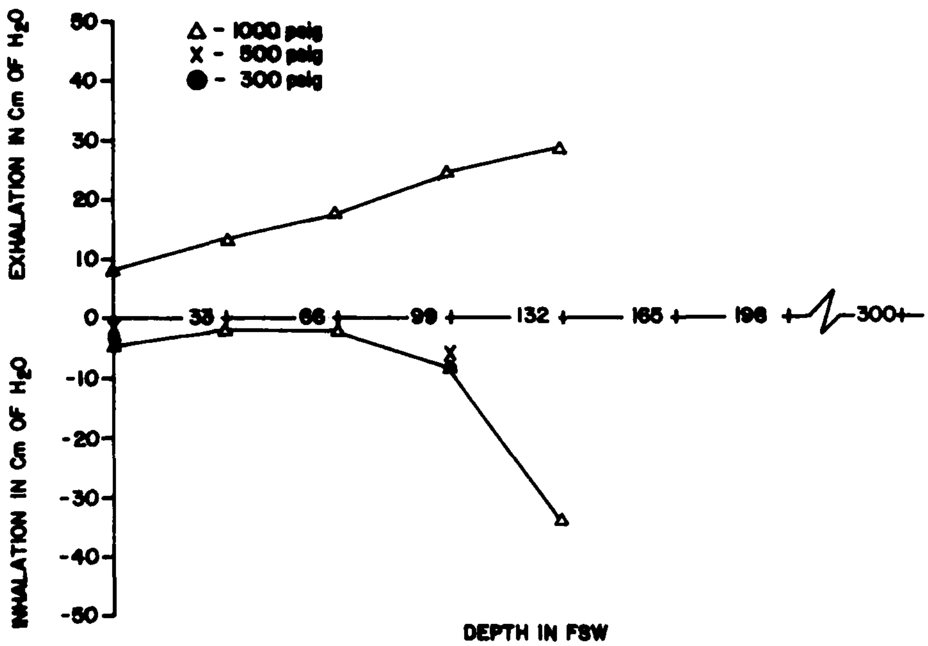

Figure 6D-4. Scubapro Air I/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 75 RMV

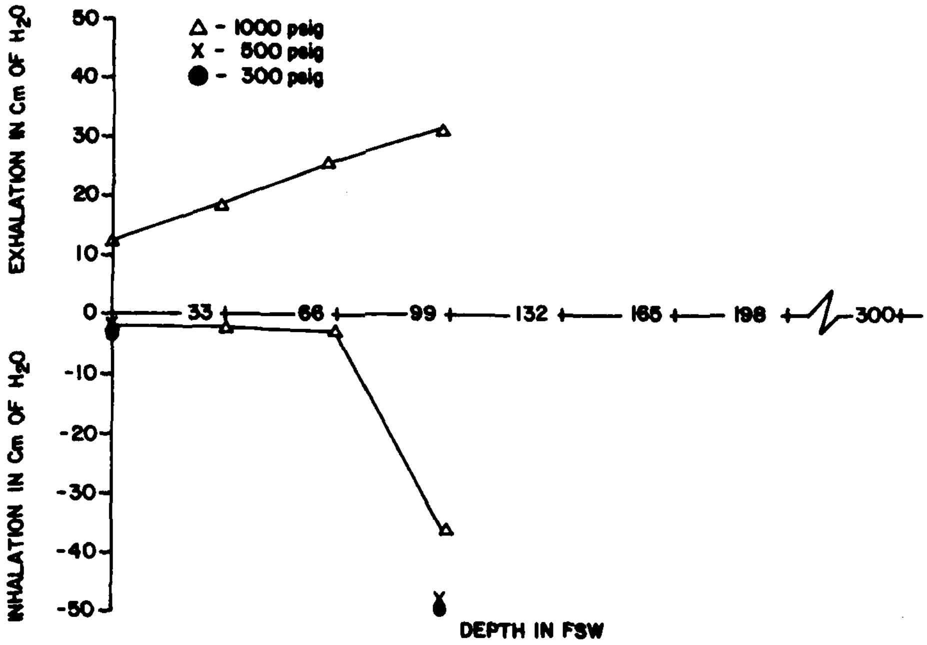

Figure 6D-5. Scubapro Air I/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 90 RMV

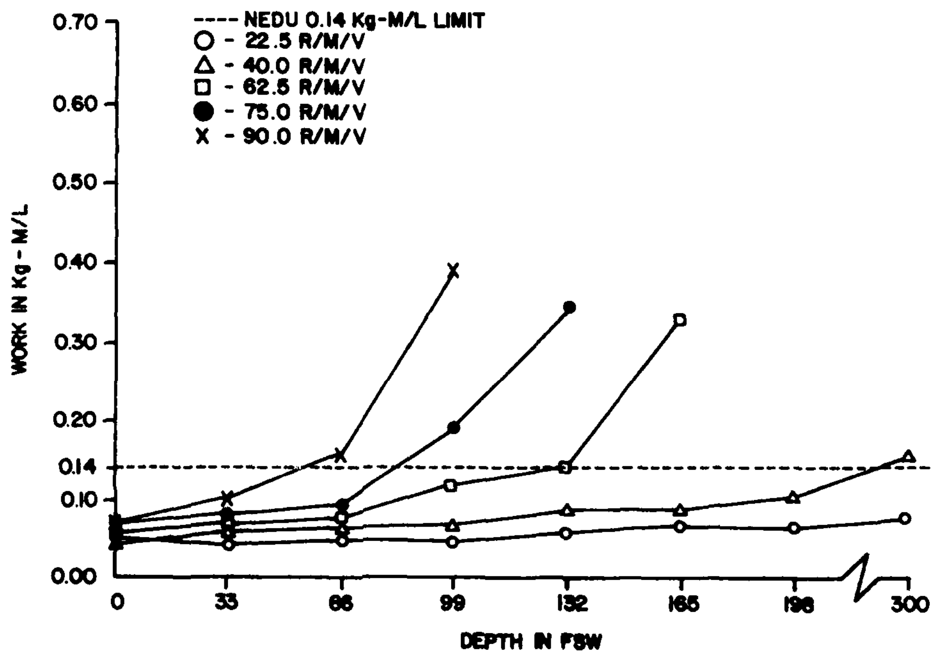

Figure 6D-6. Scubapro Air I/Mk V (4-Port Swivel)
Breathing work vs. depth at 1000 psig supply pressure

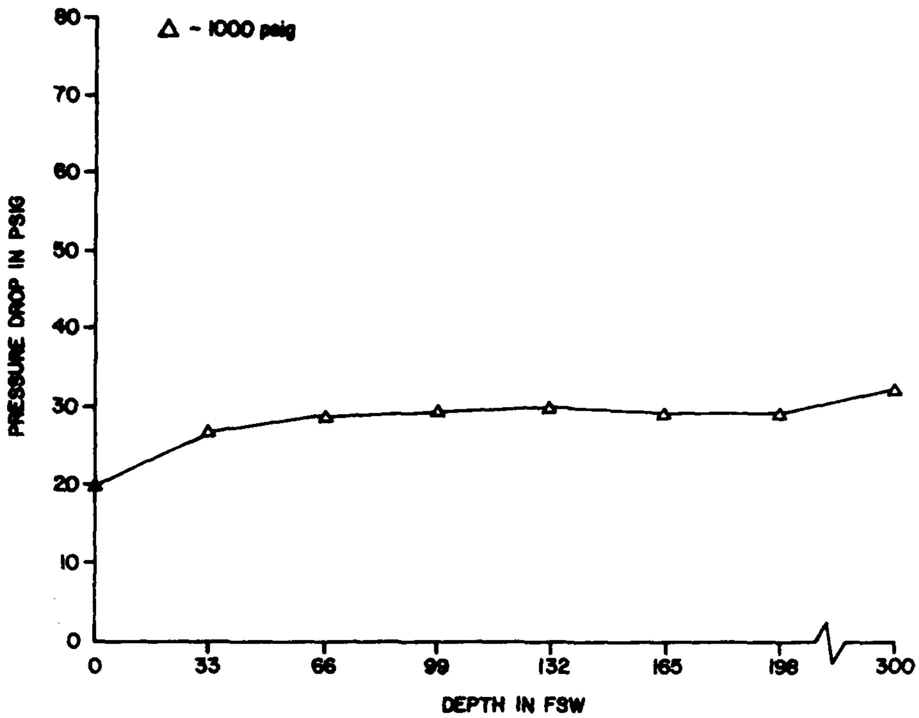

Figure 6D-7. Scubapro Air I/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 22.5 RMV

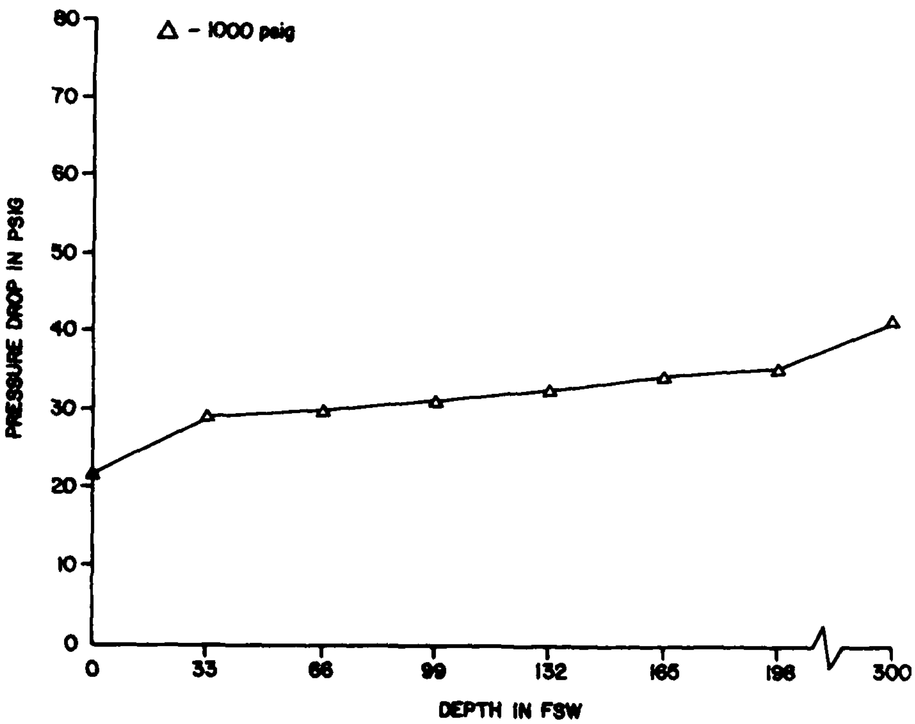

Figure 6D-8. Scubapro Air I/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 40 RMV

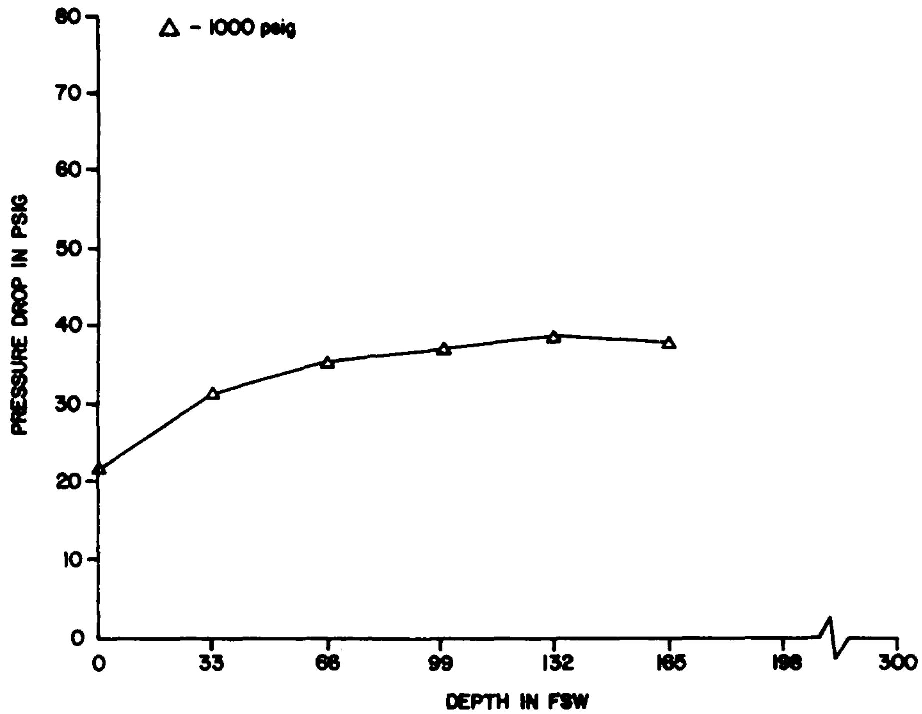

Figure 6D-9. Scubapro Air I/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 62.5 RMV

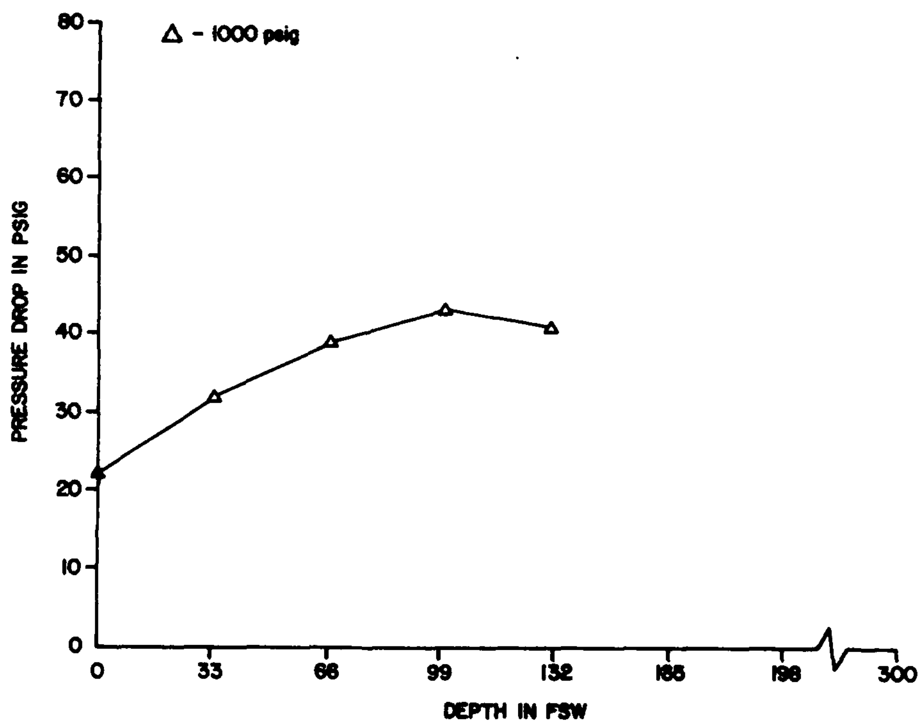

Figure 6D-10. Scubapro Air I/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 75 RMV

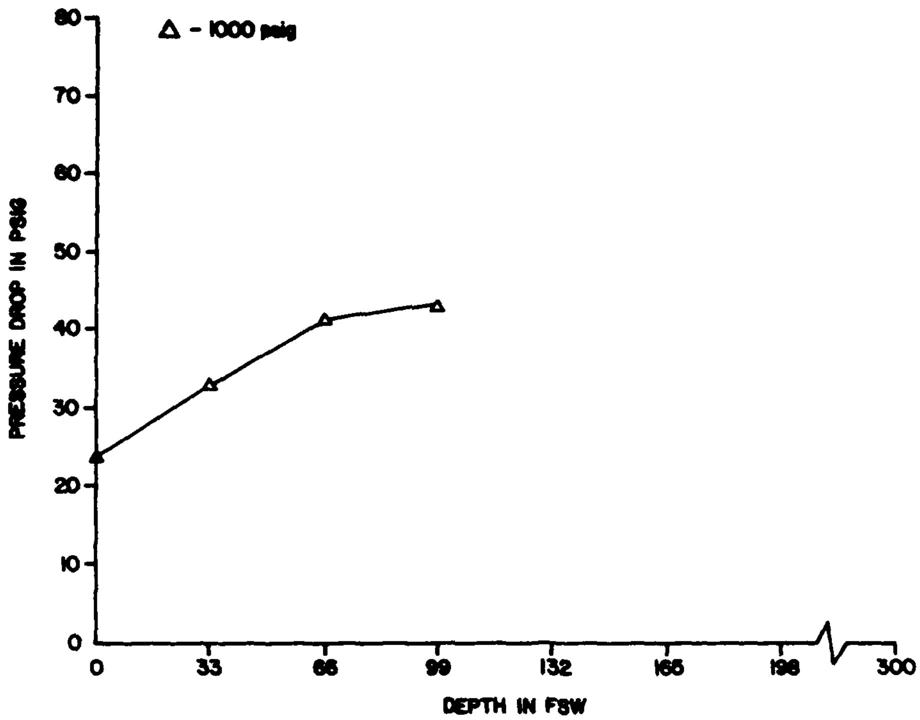

Figure 6D-11. Scubapro Air I/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 90 RMV

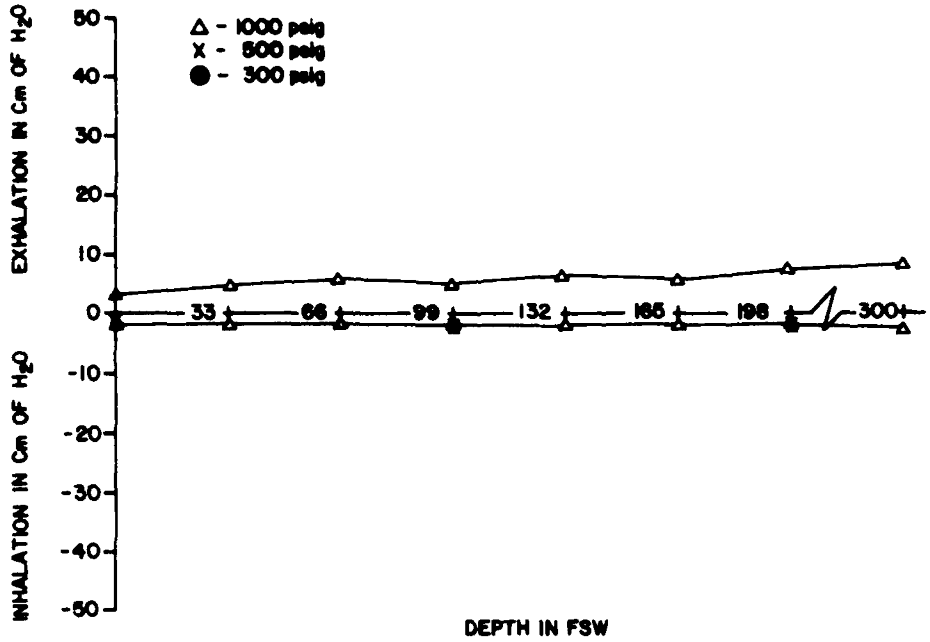

Figure 6E-1. Scubapro Air I/Mk V (5-Port Swivel)
Breathing resistance vs. depth at 22.5 RMV

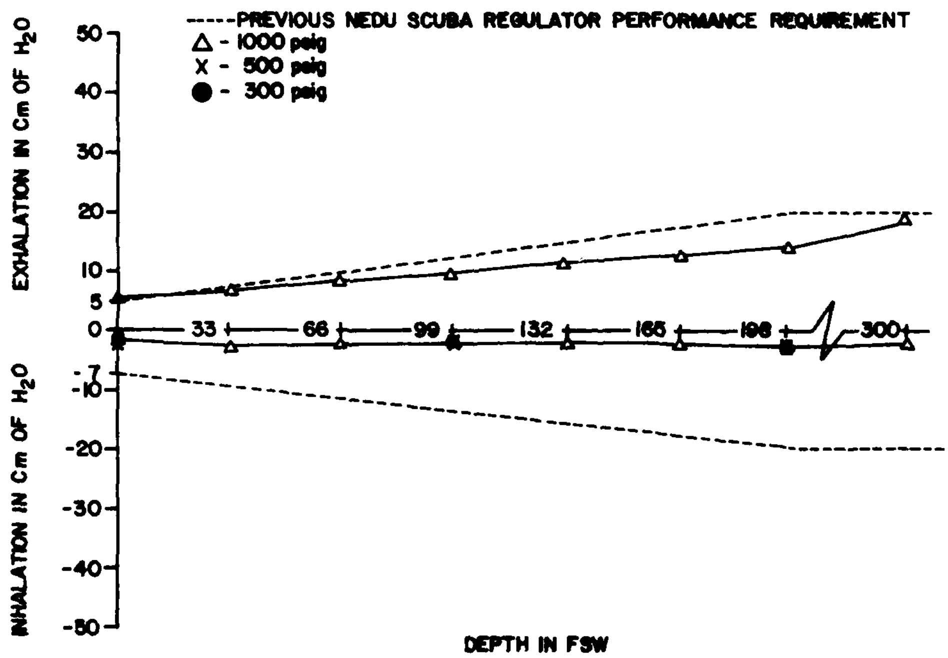

Figure 6E-2. Scubapro Air I/Mk V (5-Port Swivel)
Breathing resistance vs. depth at 40 RMV

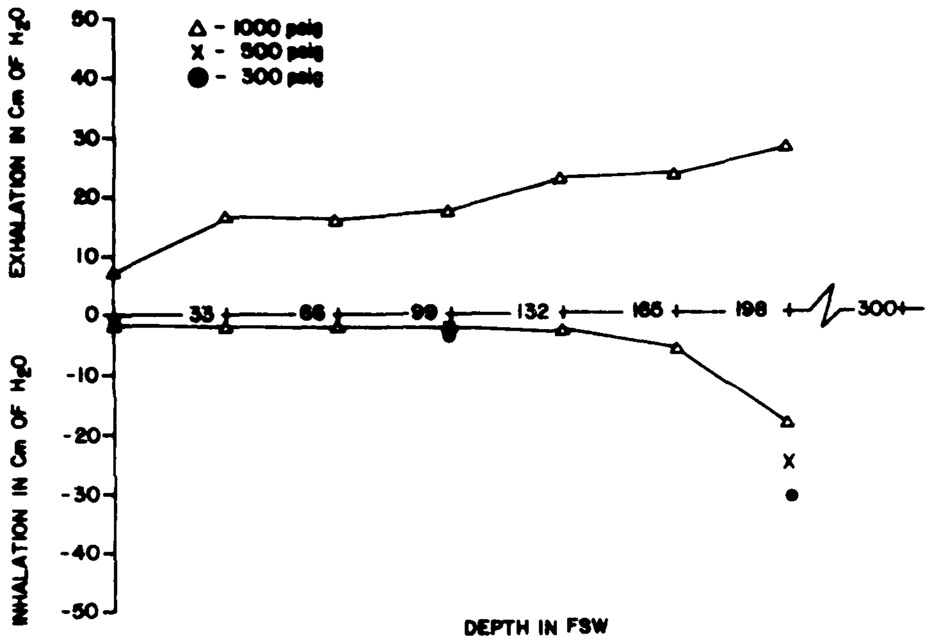

Figure 6E-3. Scubapro Air I/Mk V (5-Port Swivel)
Breathing resistance vs. depth at 62.5 RMV

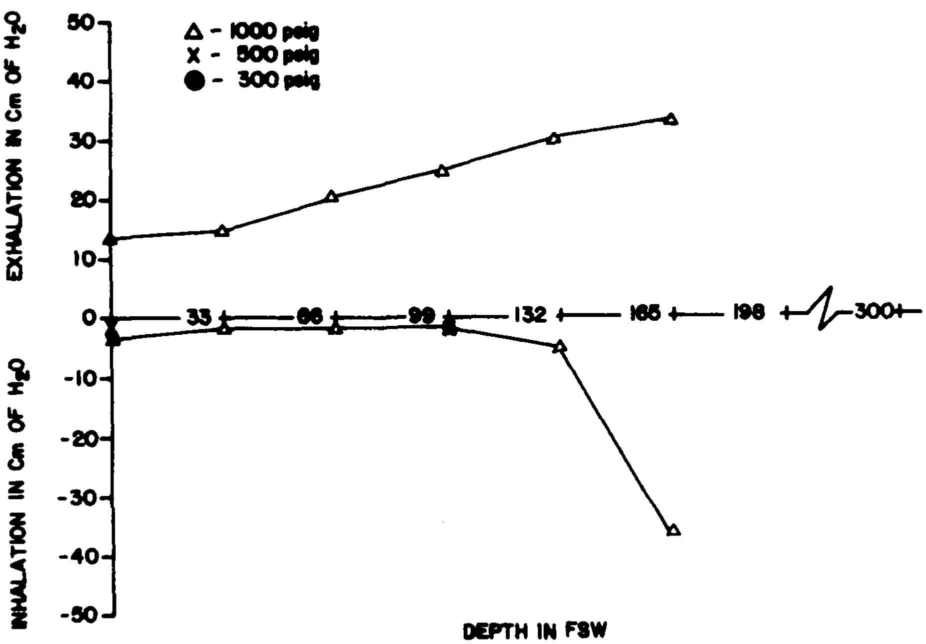

Figure 6E-4. Scubapro Air I/Mk V (5-Port Swivel)
Breathing resistance vs. depth at 75 RMV

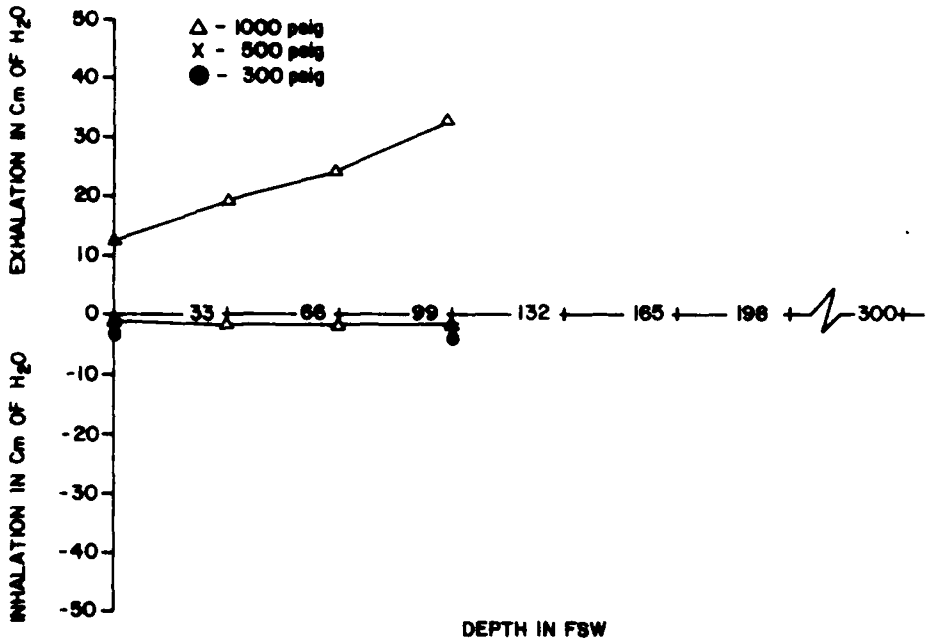

Figure 6E-5. Scubapro Air I/Mk V (5-Port Swivel)
Breathing resistance vs. depth at 90 RMV

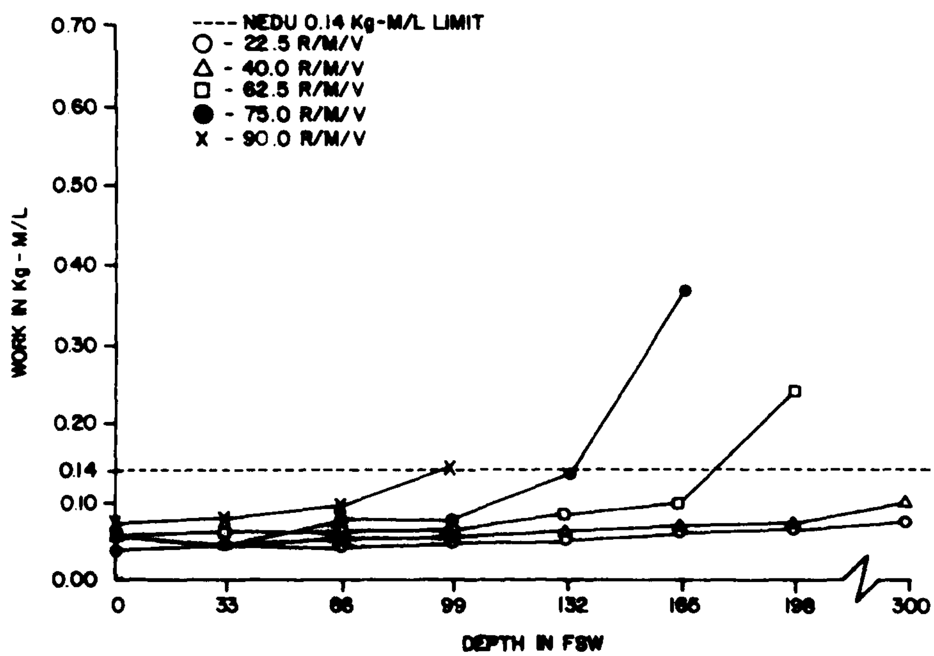

Figure 6E-6. Scubapro Air I/Mk V (5-Port Swivel)
Breathing work vs. depth at 1000 psig supply pressure

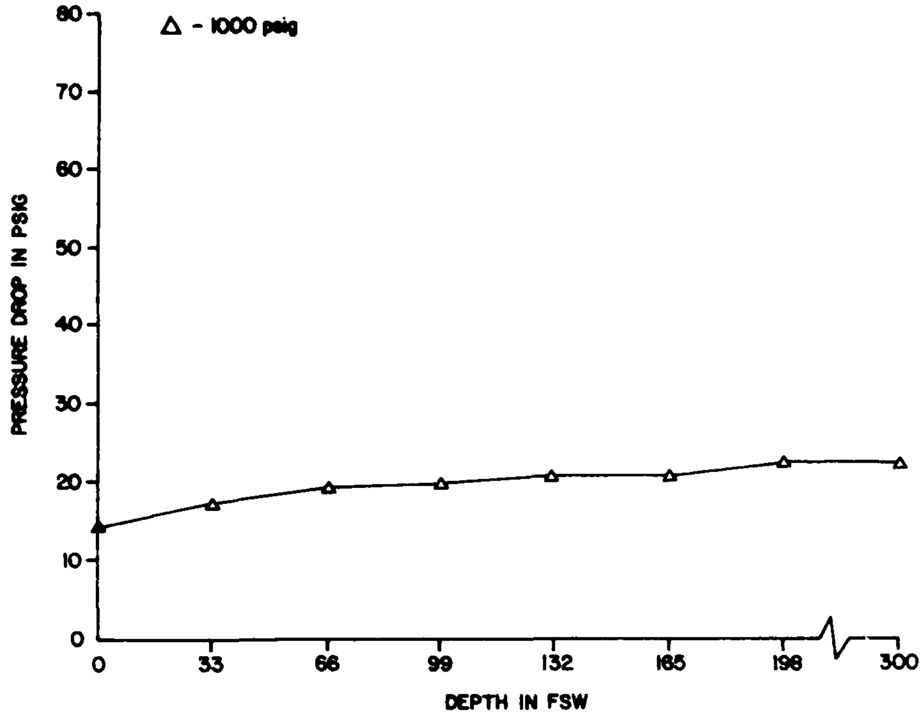

Figure 6E-7. Scubapro Air I/Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 22.5 RMV

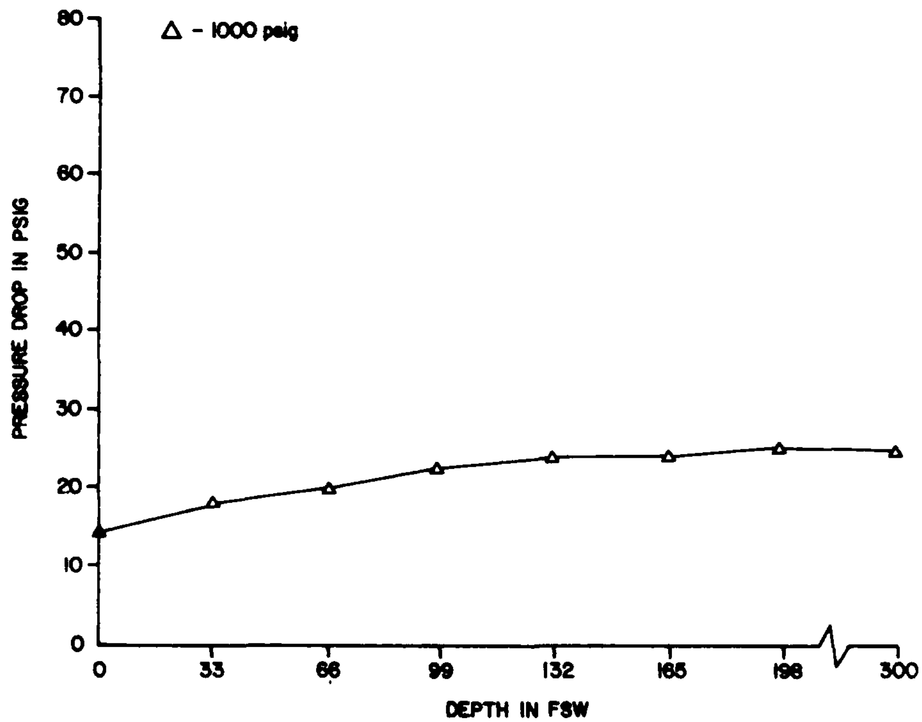

Figure 6E-8. Scubapro Air I/Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 40 RMV

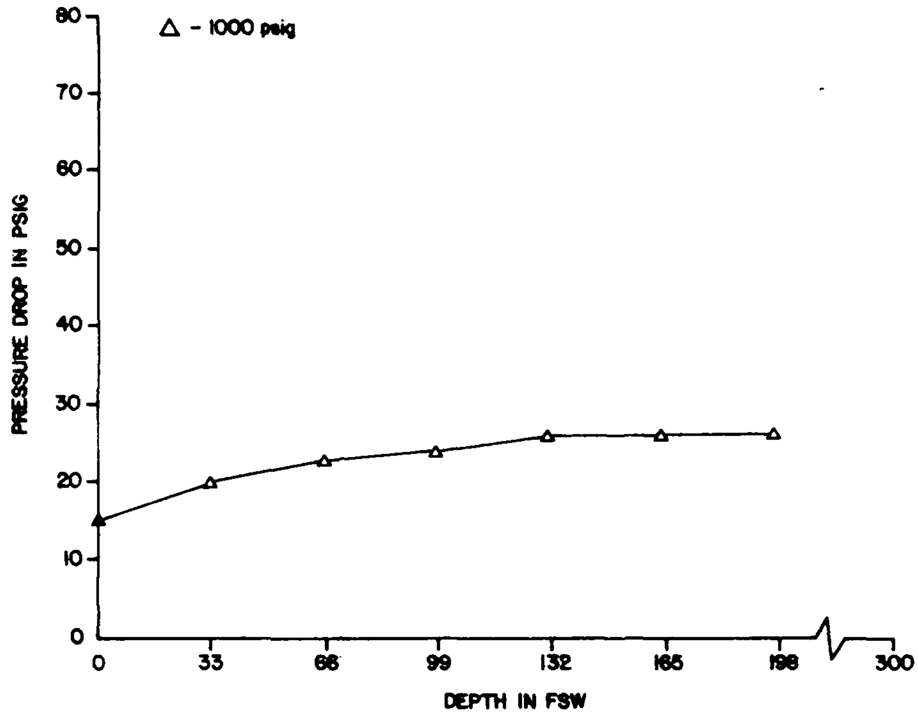

Figure 6E-9. Scubapro Air I/Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 62.5 RMV

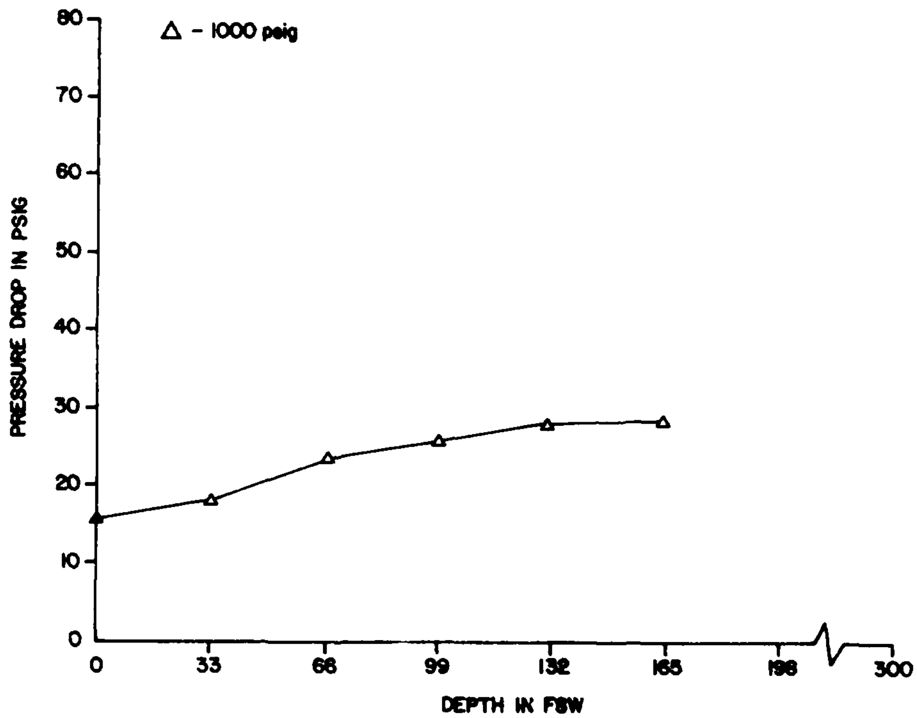

Figure 6E-10. Scubapro Air I/Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 75 RMV

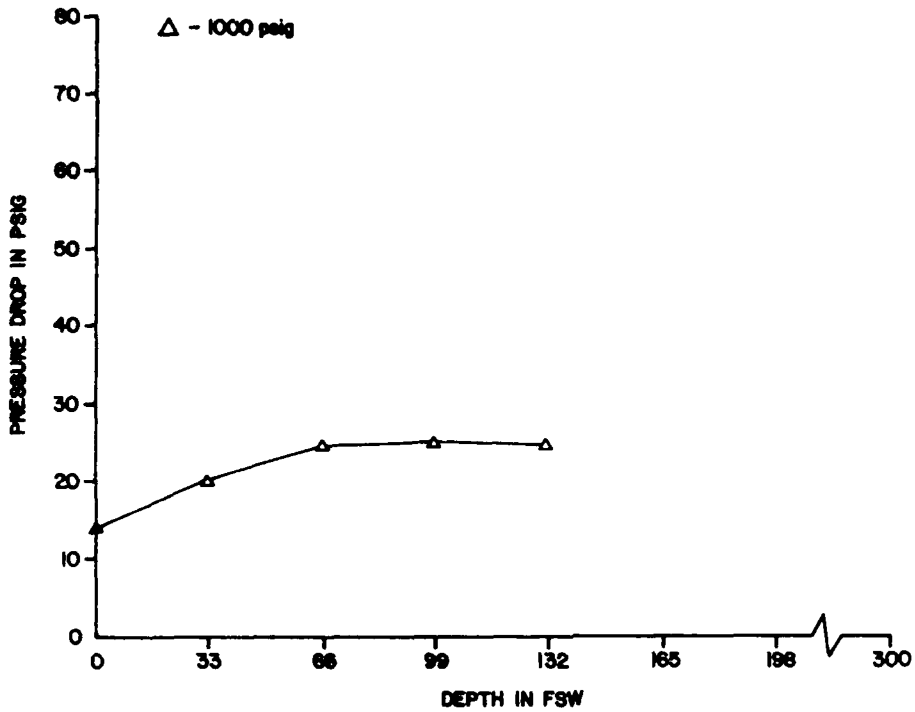

Figure 6E-11. Scubapro Air I/Mk V (5-Port Swivel)
First stage pressure drop vs. depth at 90 RMV

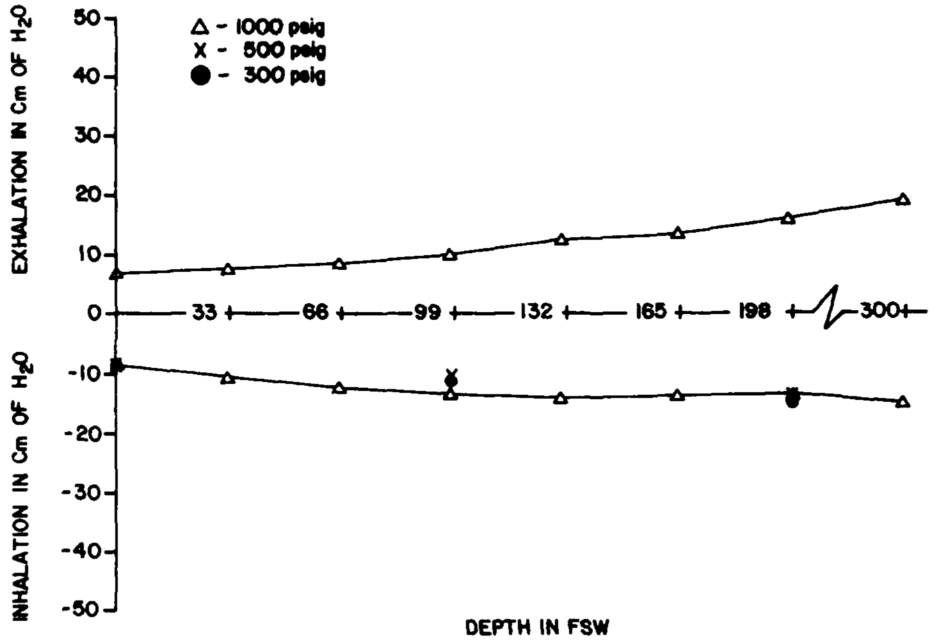

Figure 6F-1. Scubapro Air II/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 22.5 RMV

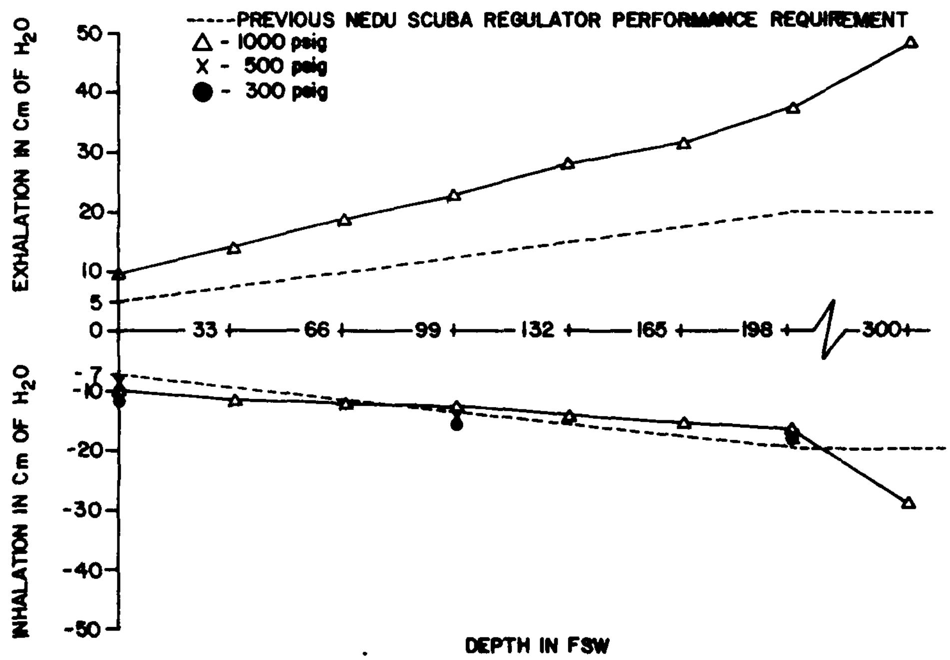

Figure 6F-2. Scubapro Air II/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 40 RMV

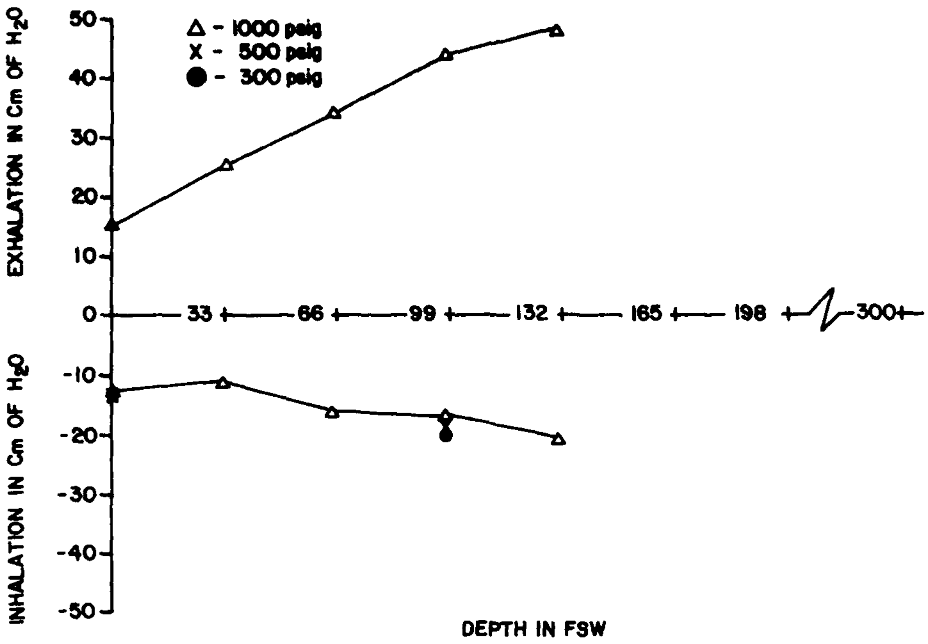

Figure 6F-3. Scubapro Air II/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 62.5 RMV

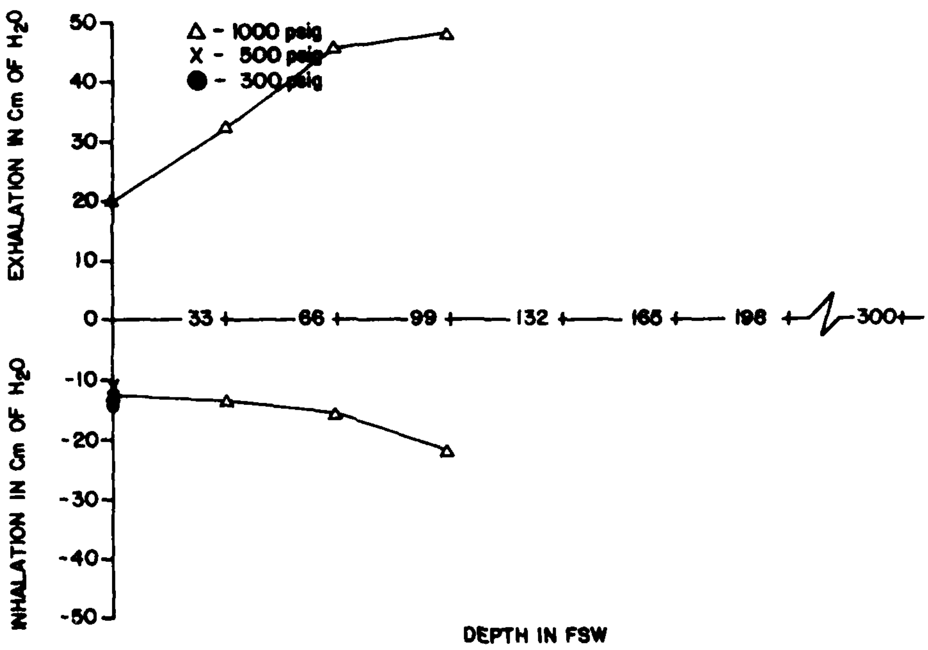

Figure 6F-4. Scubapro Air II/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 75 RMV

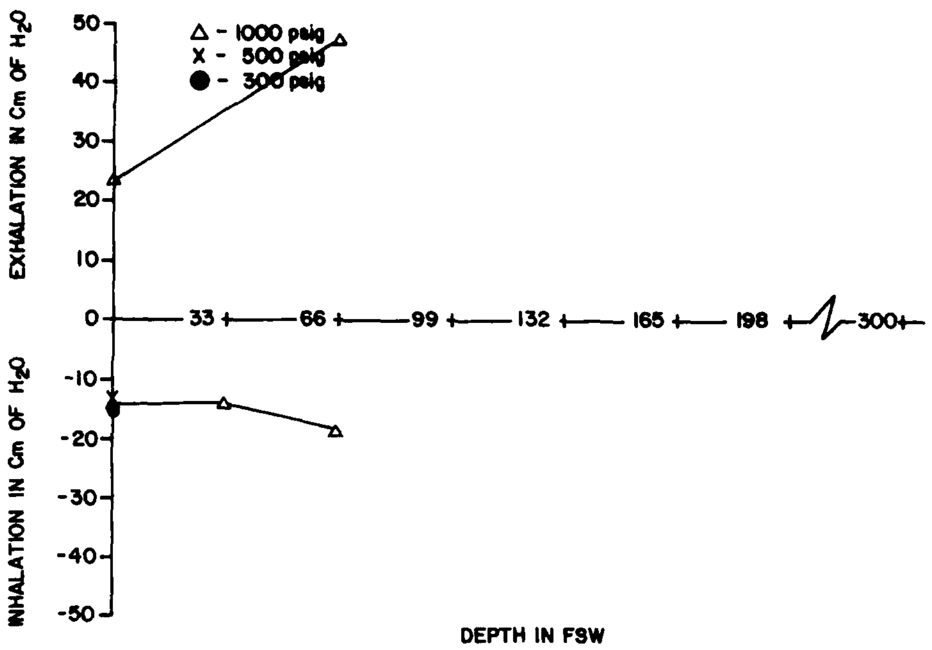

Figure 6F-5. Scubapro Air II/Mk V (4-Port Swivel)
Breathing resistance vs. depth at 90 RMV

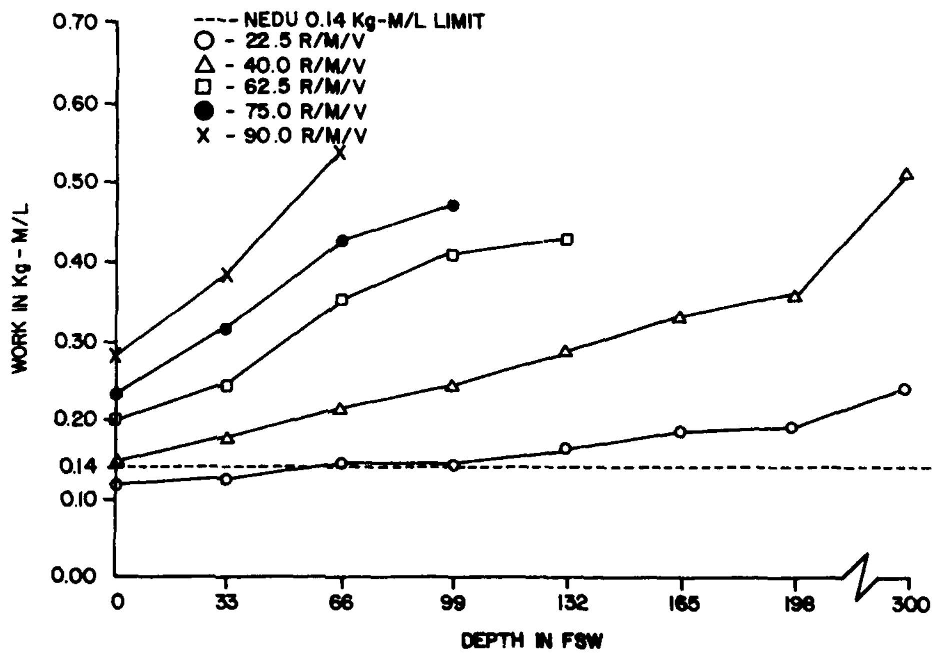

Figure 6F-6. Scubapro Air II/Mk V (4-Port Swivel)
Breathing work vs. depth at 1000 psig supply pressure

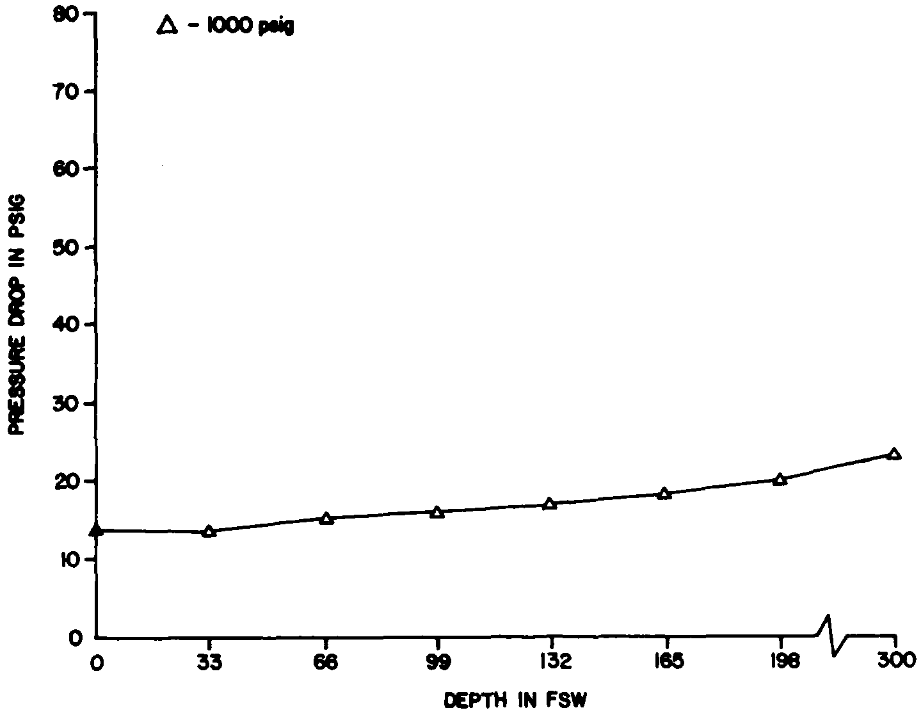

Figure 6F-7. Scubapro Air II/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 22.5 RMV

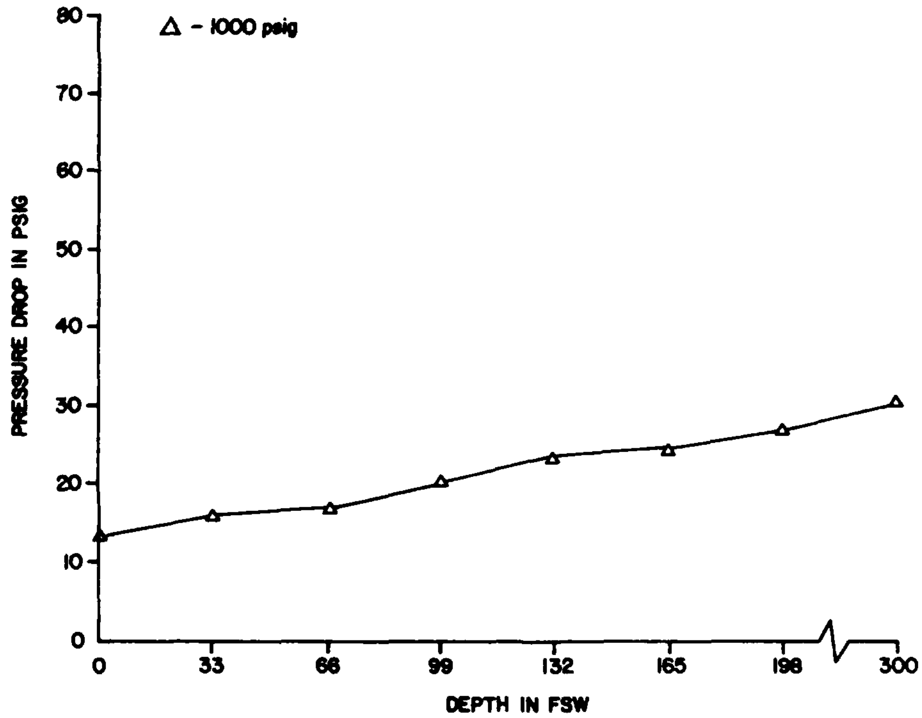

Figure 6F-8. Scubapro Air II/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 40 RMV

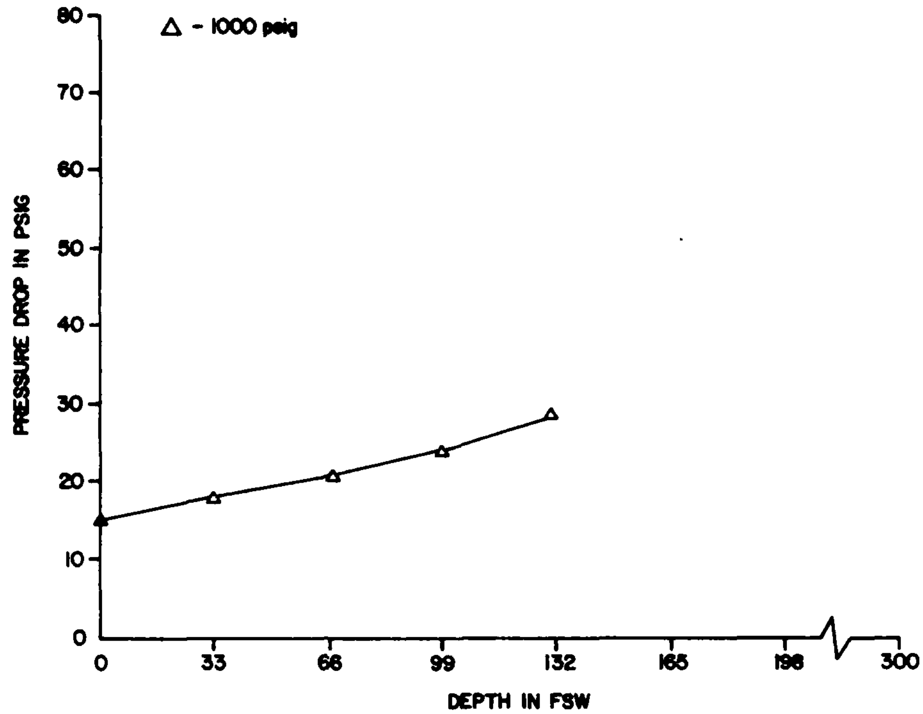

Figure 6F-9. Scubapro Air II/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 62.5 RMV

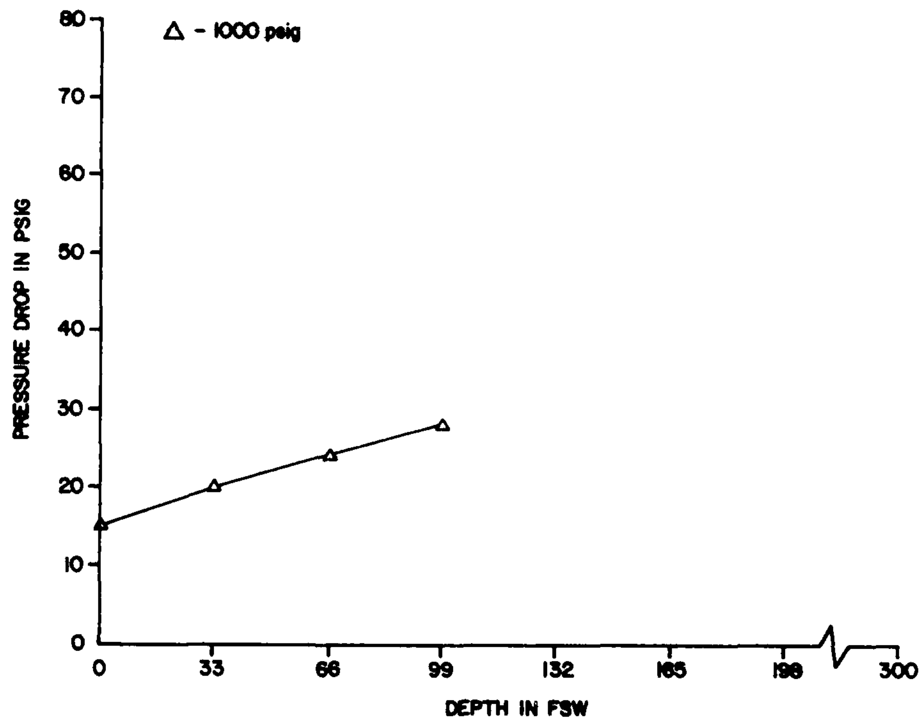

Figure 6F-10. Scubapro Air II/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 75 RMV

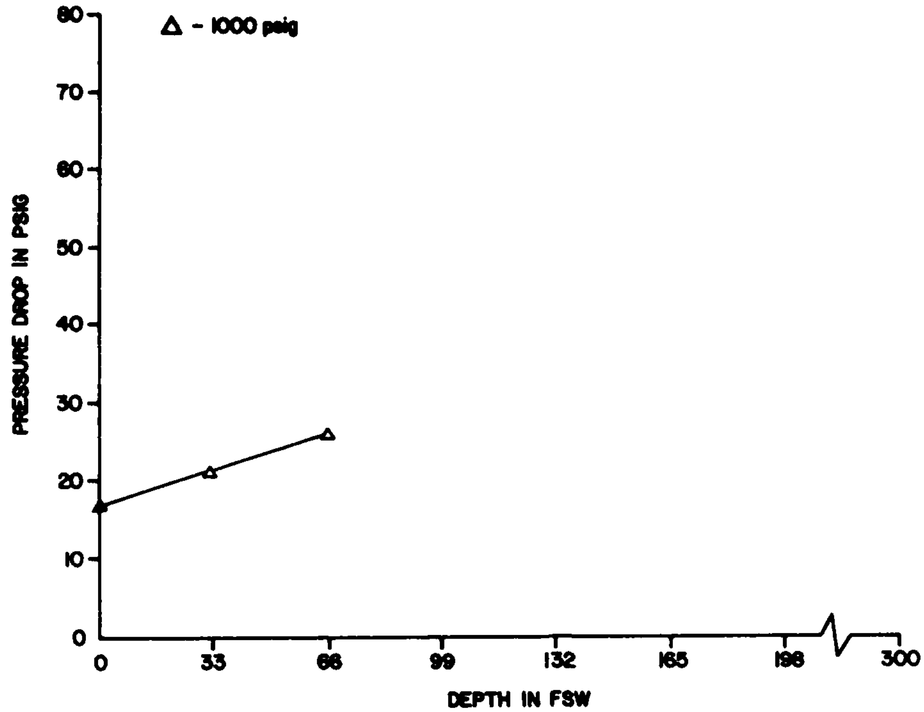

Figure 6F-11. Scubapro Air II/Mk V (4-Port Swivel)
First stage pressure drop vs. depth at 90 RMV

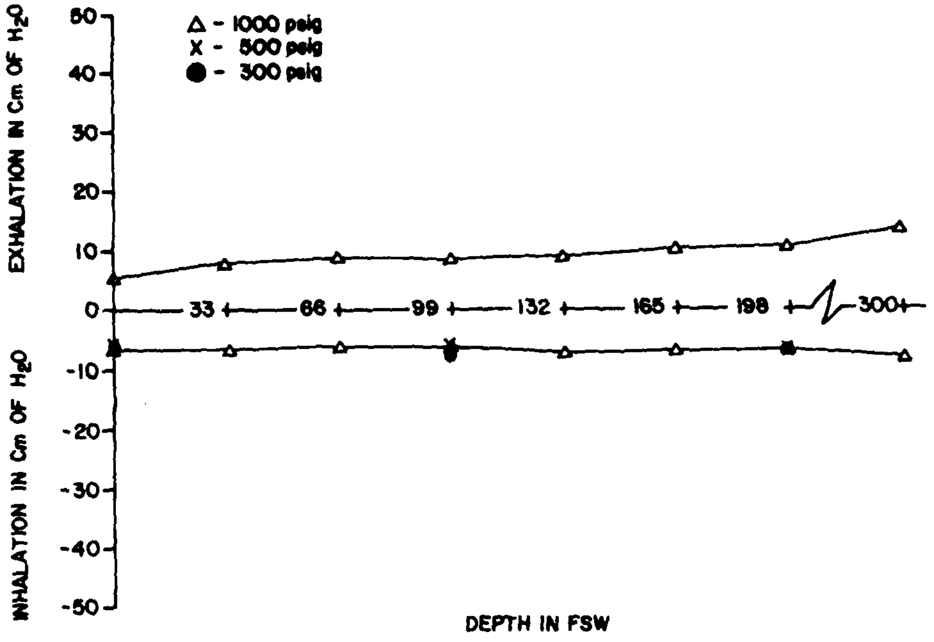

Figure 7A-1. Seapro FSDS-10
Breathing resistance vs. depth at 22.5 RMV

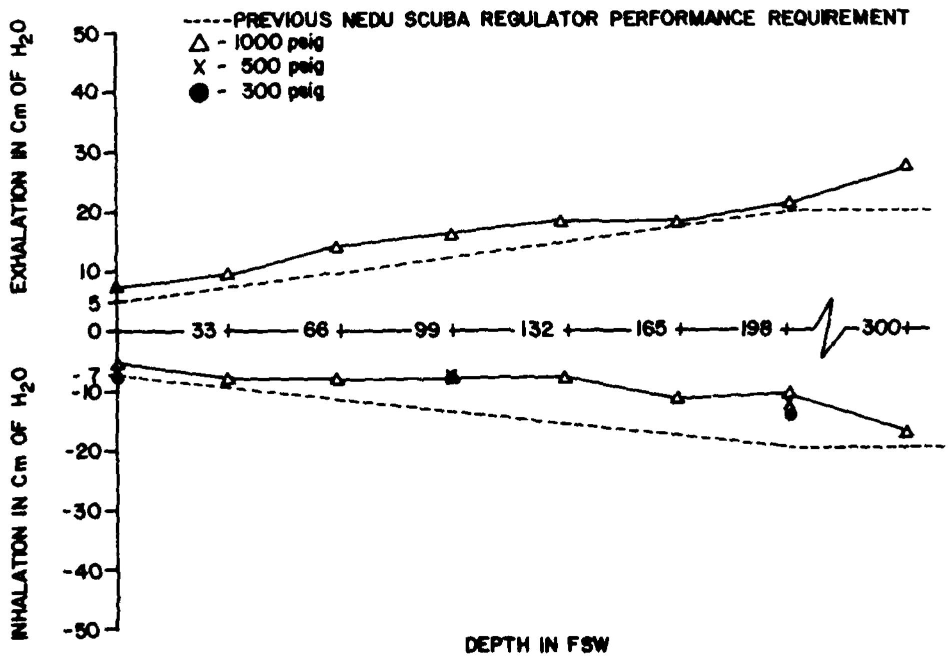

Figure 7A-2. Seapro FSDS-10
Breathing resistance vs. depth at 40 RMV

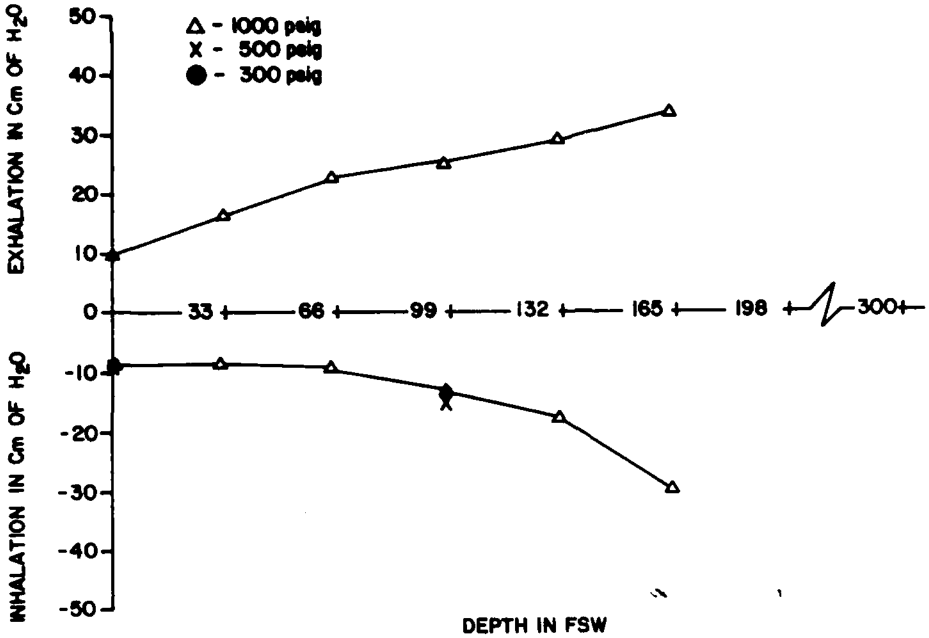

Figure 7A-3. Seapro FSDS-10
Breathing resistance vs. depth at 62.5 RMV

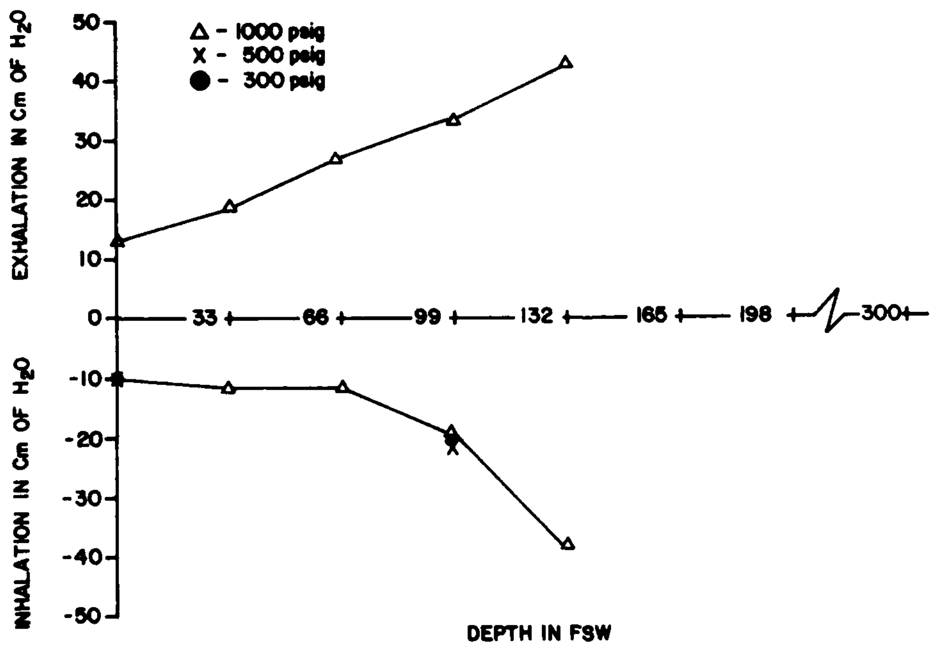

Figure 7A-4. Seapro FSDS-10
Breathing resistance vs. depth at 75 RMV

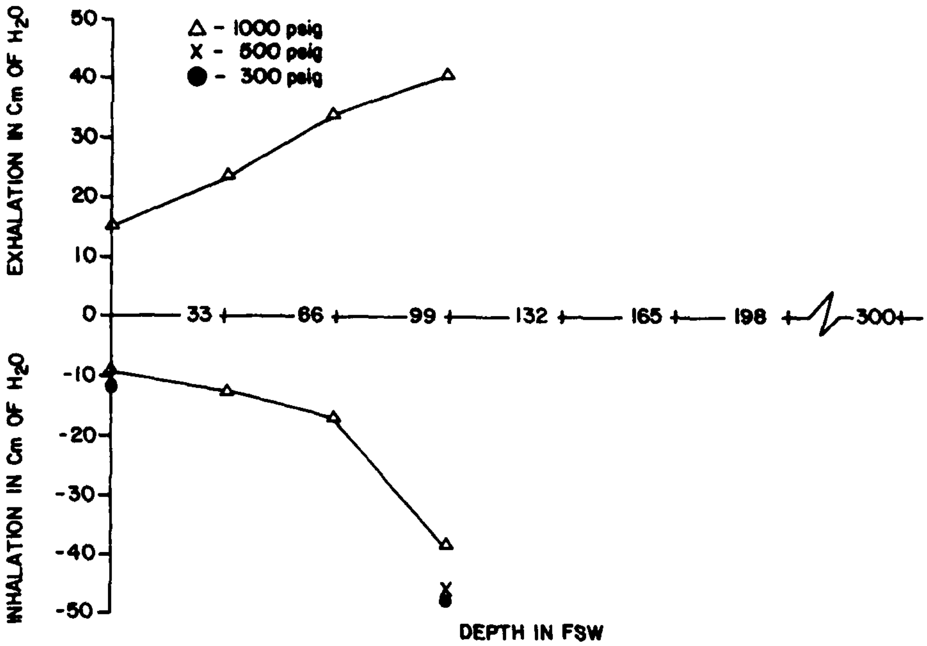

Figure 7A-5. Seapro FSDS-10
Breathing resistance vs. depth at 90 RMV

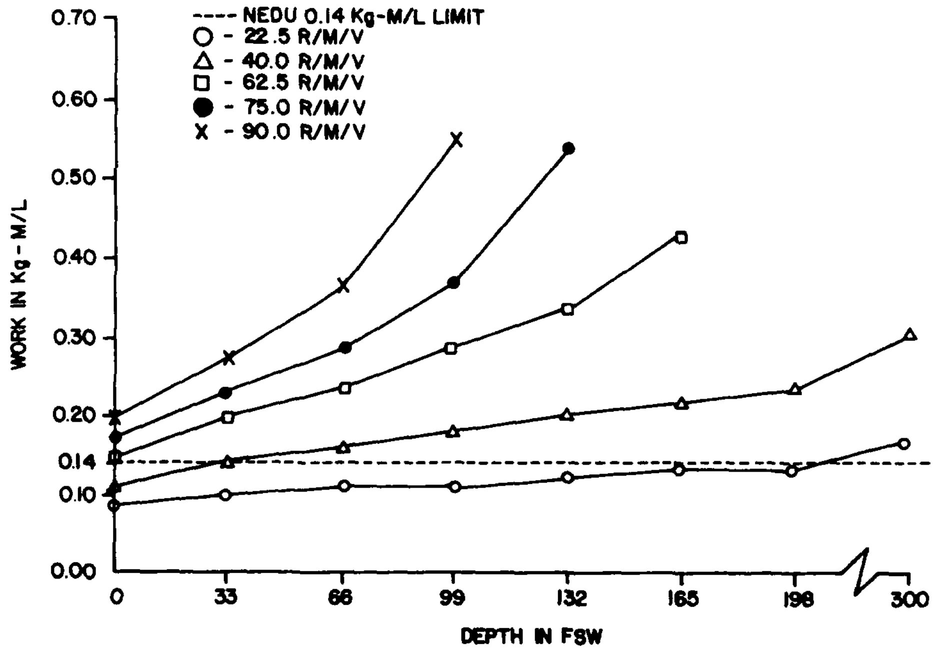

Figure 7A-6. Seapro FSDS-10
Breathing work vs. depth at 1000 psig supply pressure

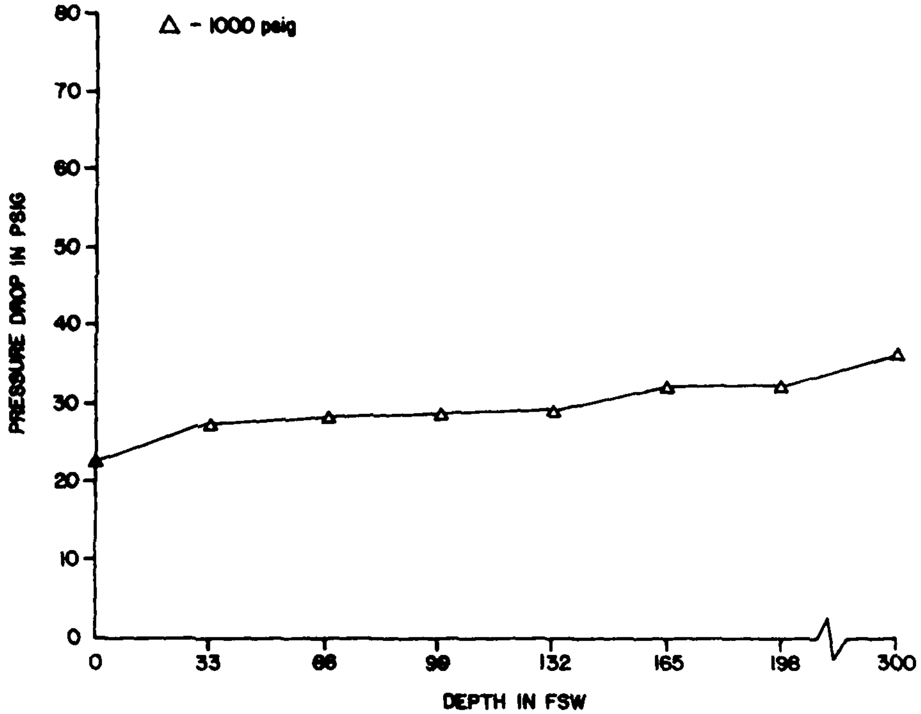

Figure 7A-7. Seapro FSDS-10
First stage pressure drop vs. depth at 22.5 RMV

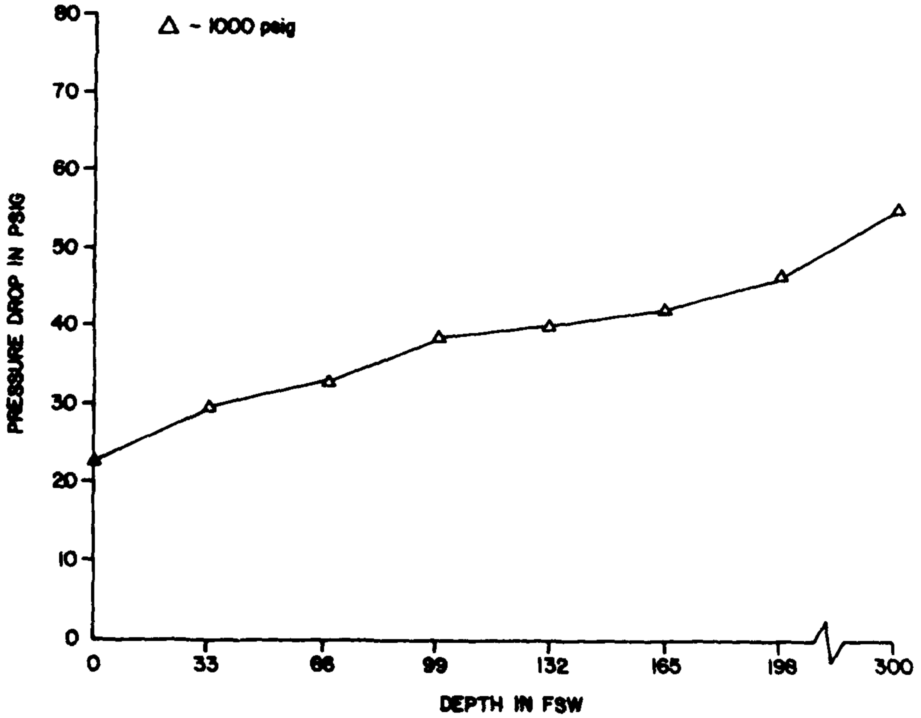

Figure 7A-8. Seapro FSDS-10
First stage pressure drop vs. depth at 40 RMV

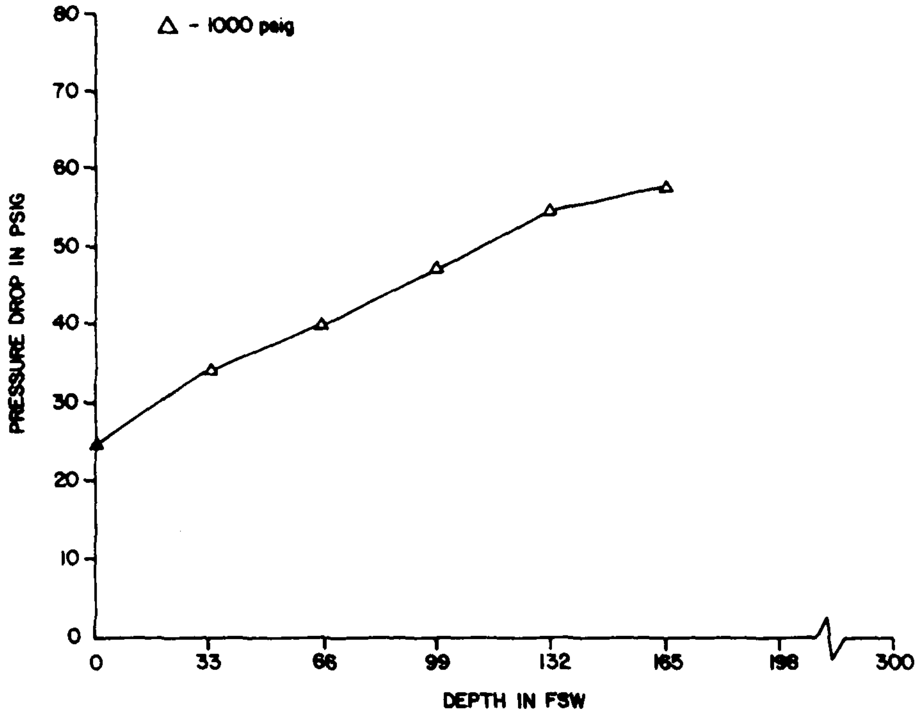

Figure 7A-9. Seapro FSDS-10
First stage pressure drop vs. depth at 62.5 RMV

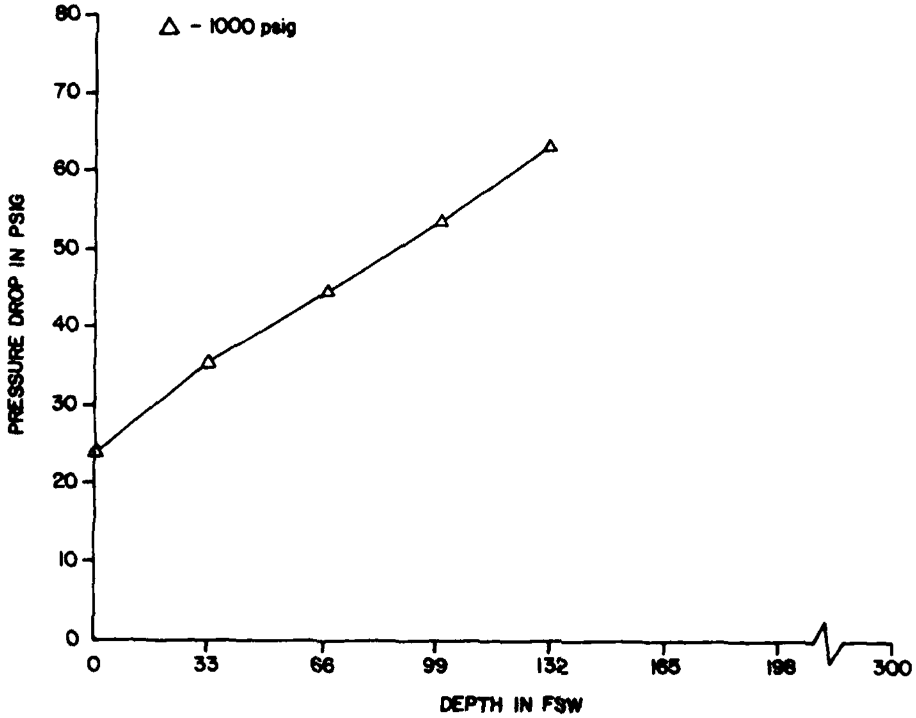

Figure 7A-10. Seapro FSDS-10
First stage pressure drop vs. depth at 75 RMV

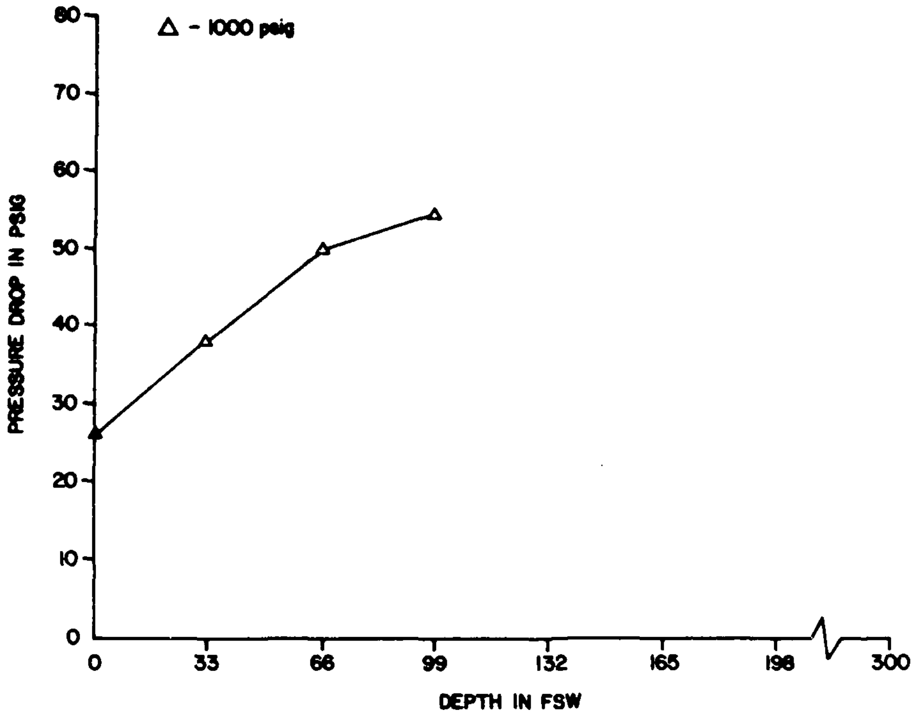

Figure 7A-11. Seapro FSDS-10
First stage pressure drop vs. depth at 90 RMV

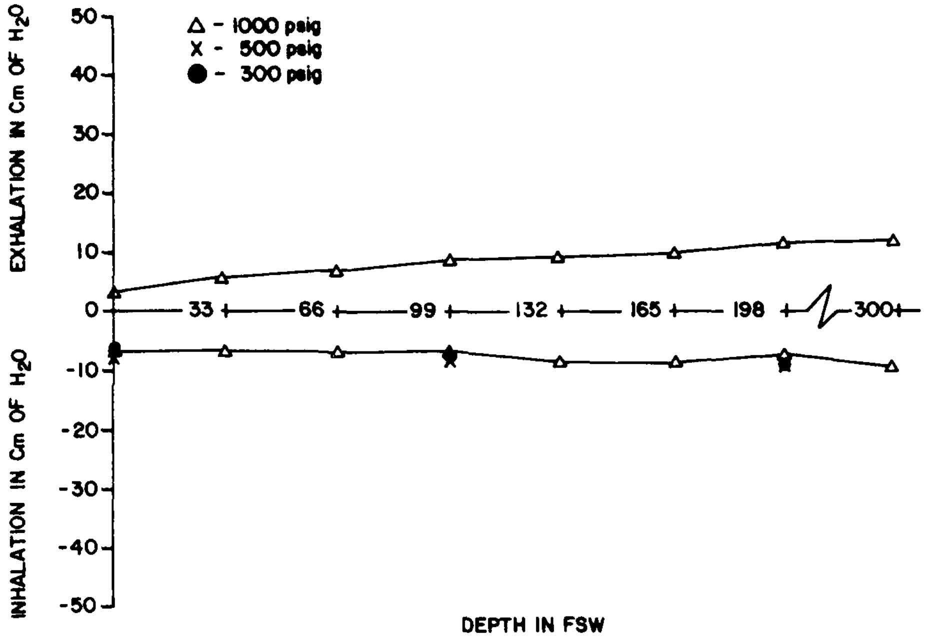

Figure 7B-1. Seapro FSDS-50
Breathing resistance vs. depth at 22.5 RMV

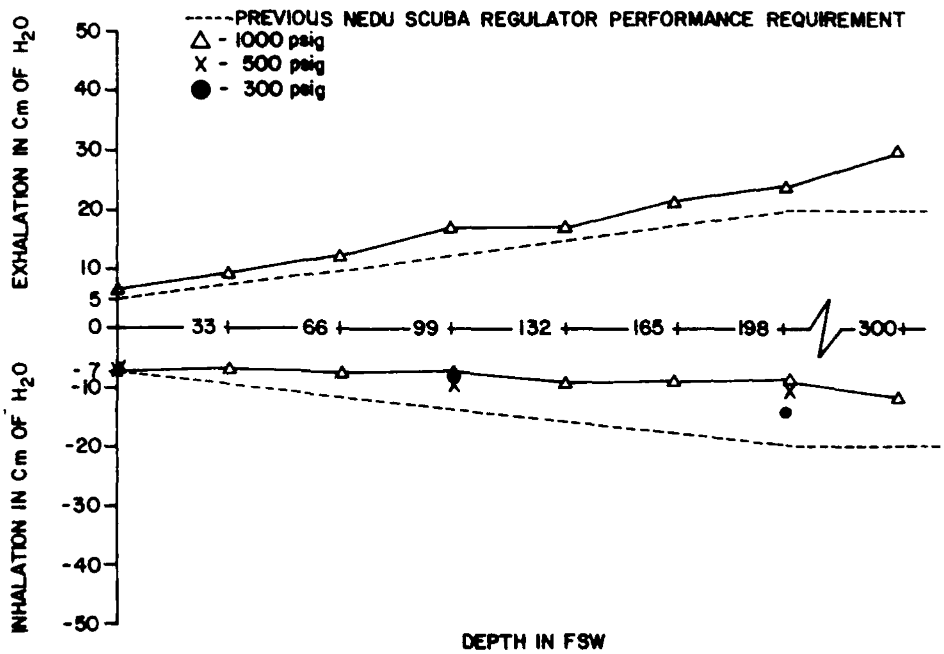

Figure 7B-2. Seapro FSDS-50
Breathing resistance vs. depth at 40 RMV

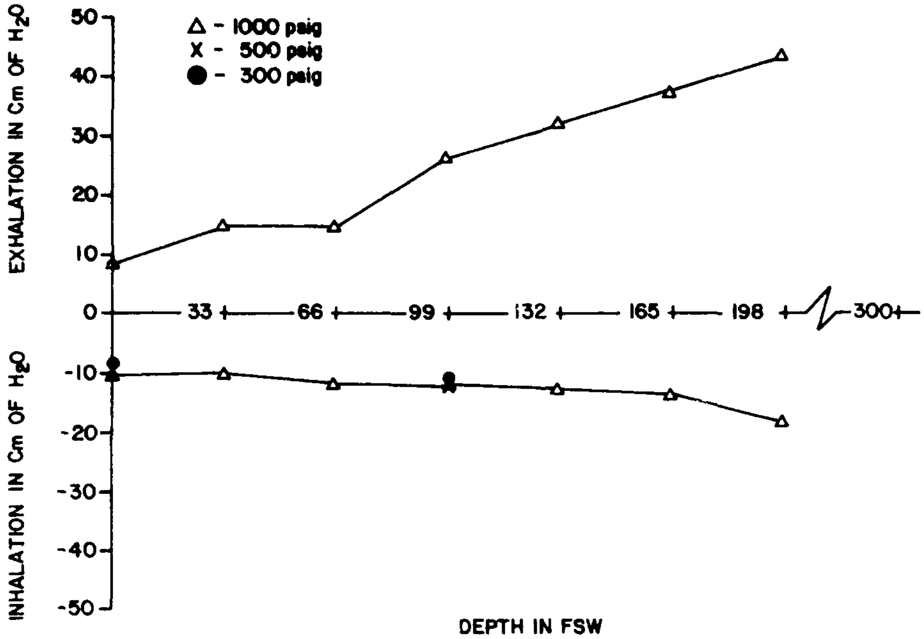

Figure 7B-3. Seapro FSDS-50
Breathing resistance vs. depth at 62.5 RMV

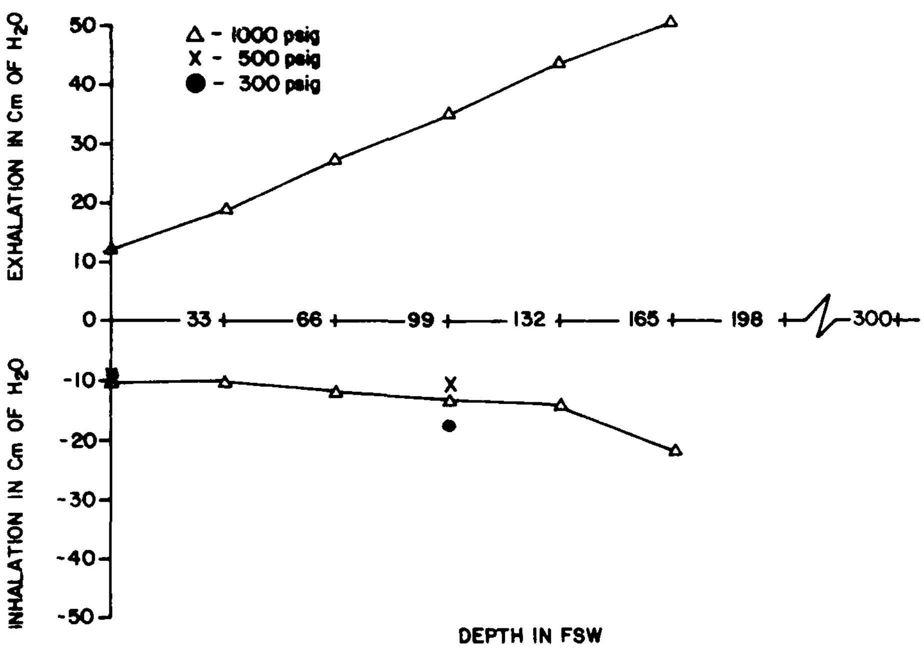

Figure 7B-4. Seapro FSDS-50
Breathing resistance vs. depth at 75 RMV

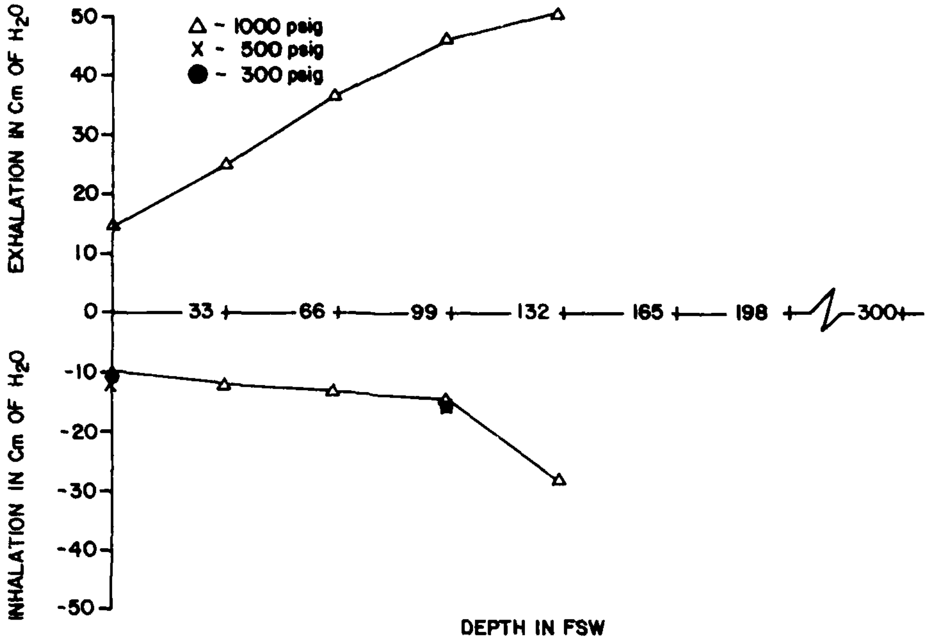

Figure 7B-5. Seapro FSDS-50
Breathing resistance vs. depth at 90 RMV

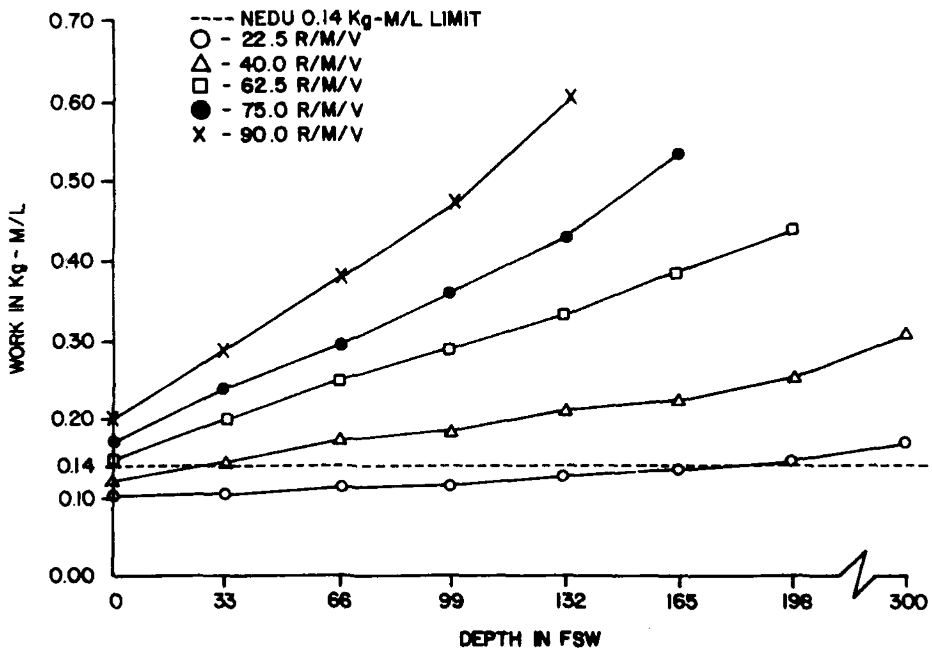

Figure 7B-6. Seapro FSDS-50
Breathing work vs. depth at 1000 psig supply pressure

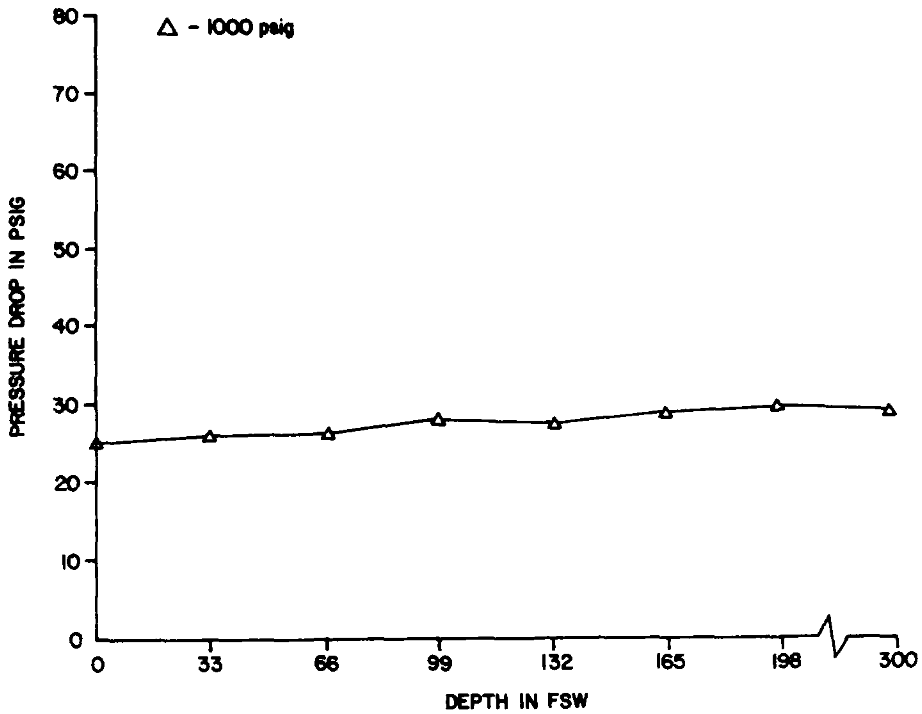

Figure 7B-7. Seapro FSDS-50
First stage pressure drop vs. depth at 22.5 RMV

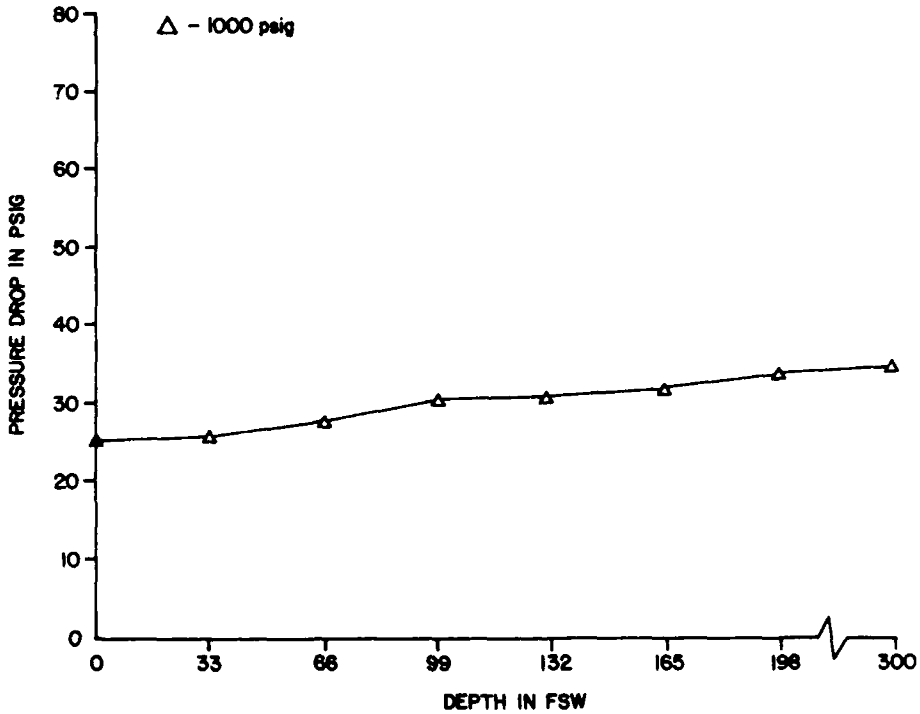

Figure 7B-8. Seapro FSDS-50
First stage pressure drop vs. depth at 40 RMV

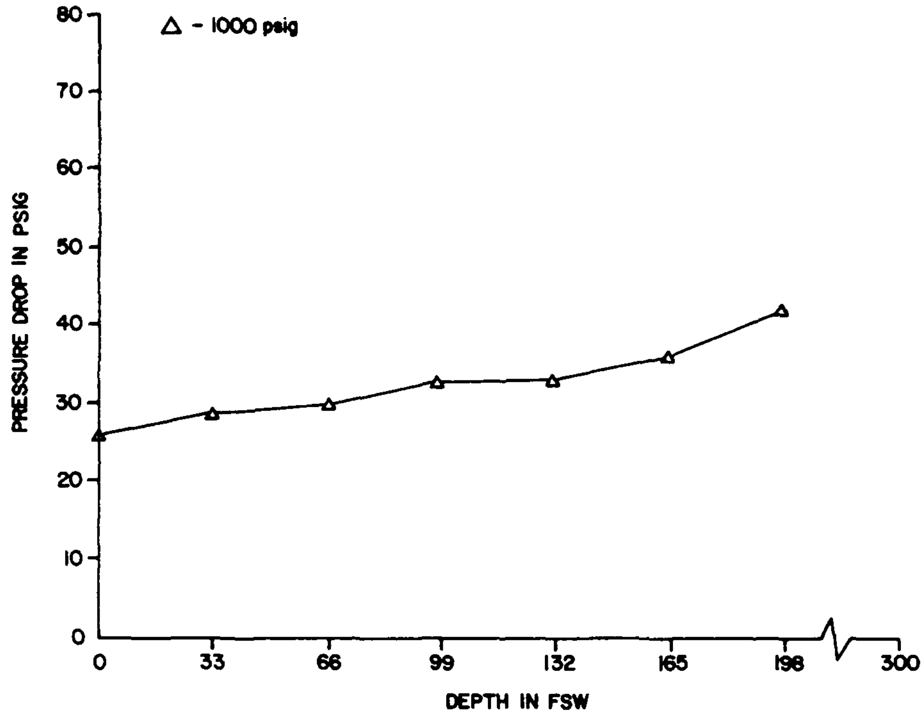

Figure 7B-9. Seapro FSDS-50
First stage pressure drop vs. depth at 62.5 RMV

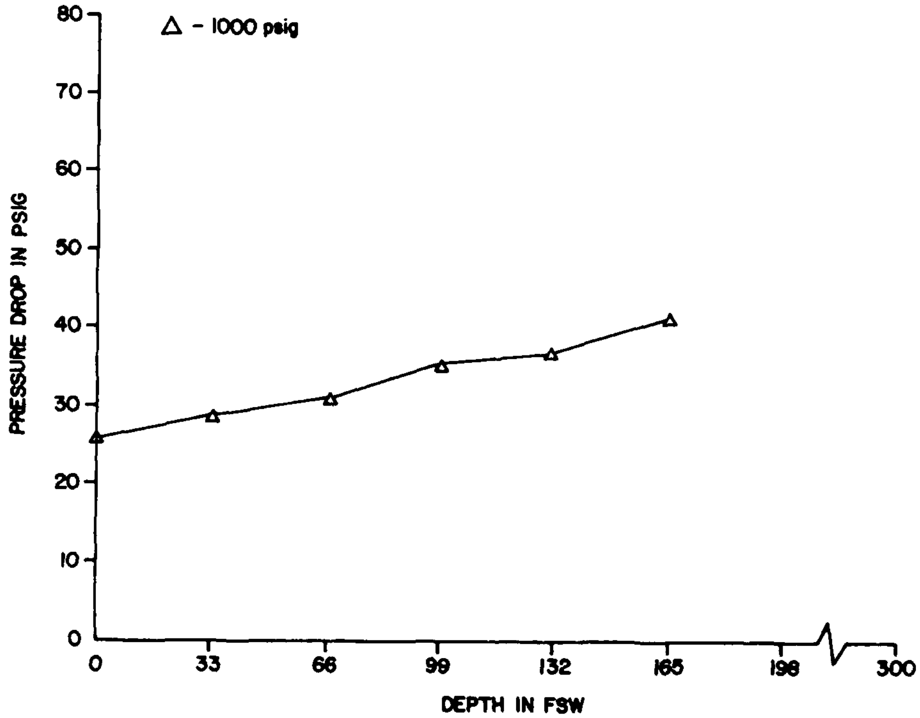

Figure 7B-10. Seapro FSDS-50
First stage pressure drop vs. depth at 75 RMV

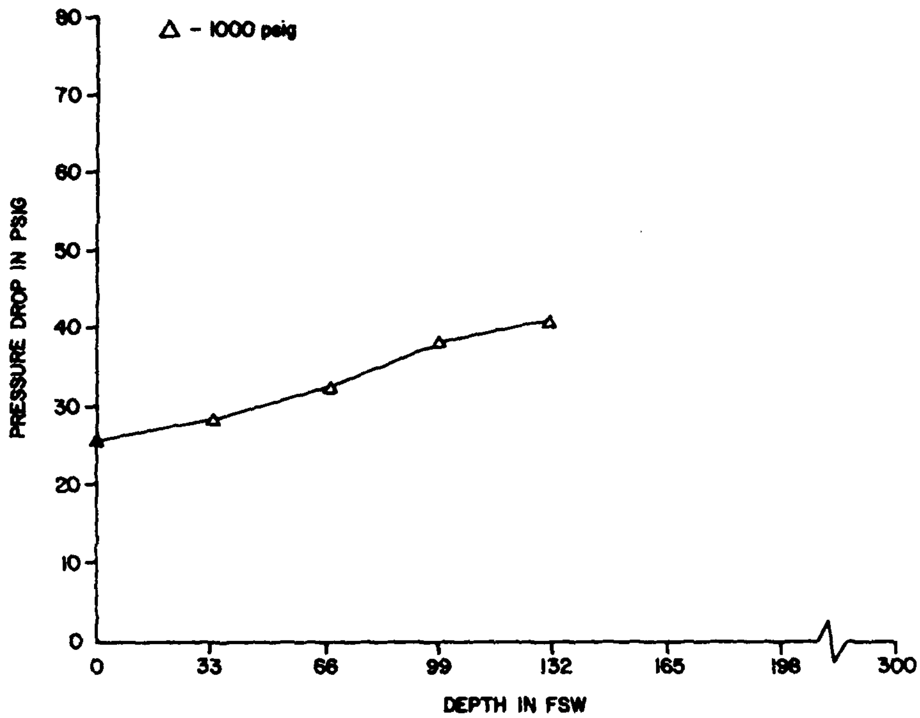

Figure 7B-11. Seapro FSDS-50
First stage pressure drop vs. depth 90 RMV

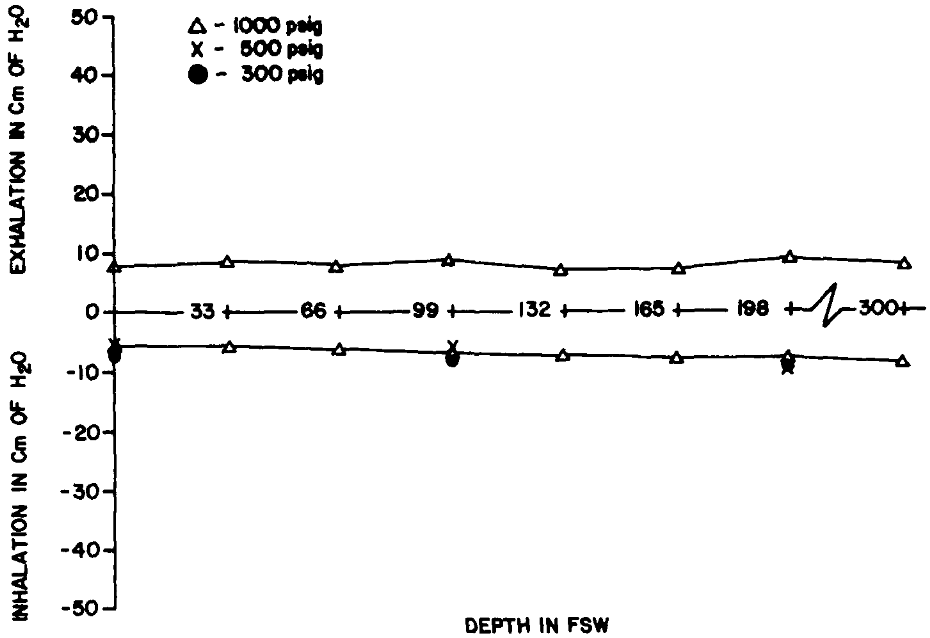

Figure 8A-1. Sherwood Selpac SRB-2000
Breathing resistance vs. depth at 22.5 RMV

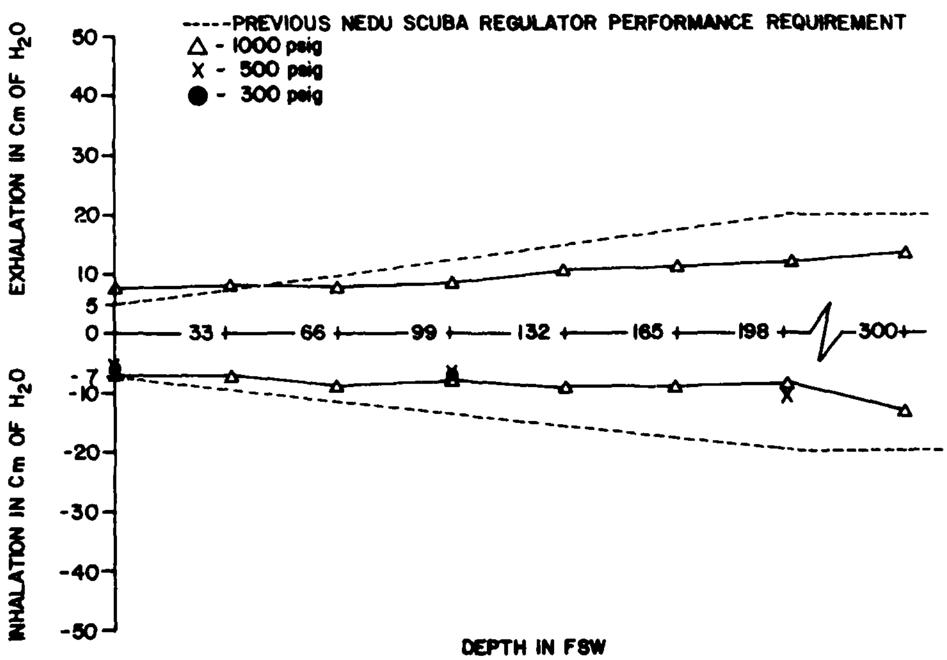

Figure 8A-2. Sherwood Selpac SRB-2000
Breathing resistance vs. depth at 40 RMV

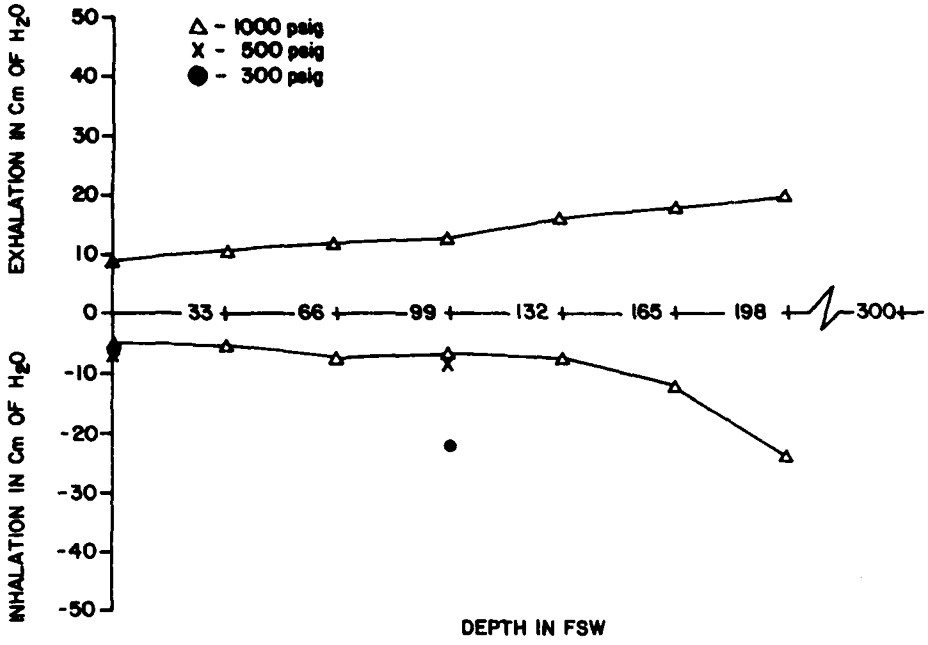

Figure 8A-3. Sherwood Selpac SRB-2000
Breathing resistance vs. depth at 62.5 RMV

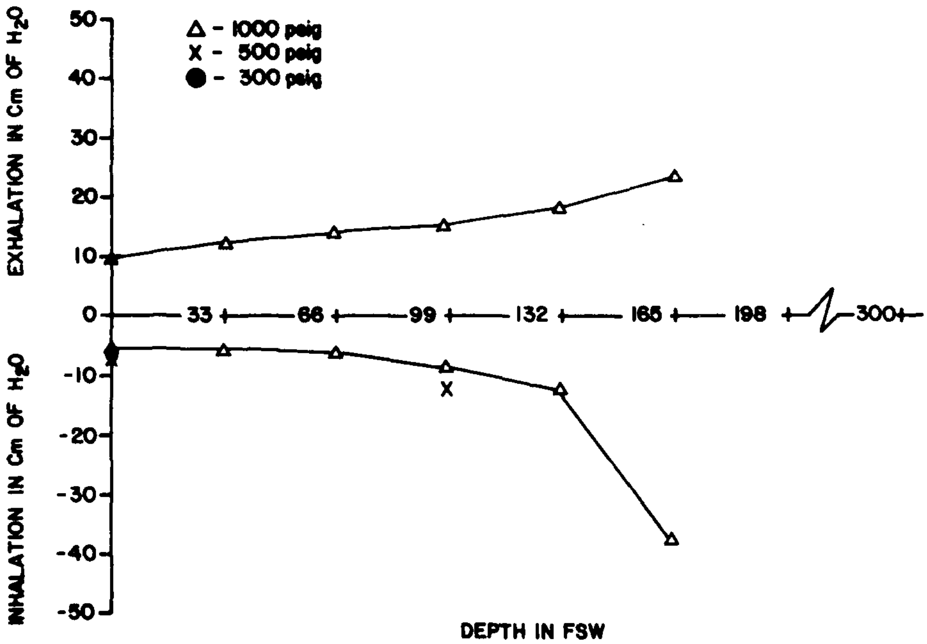

Figure 8A-4. Sherwood Selpac SRB-2000
Breathing resistance vs. depth at 75 RMV

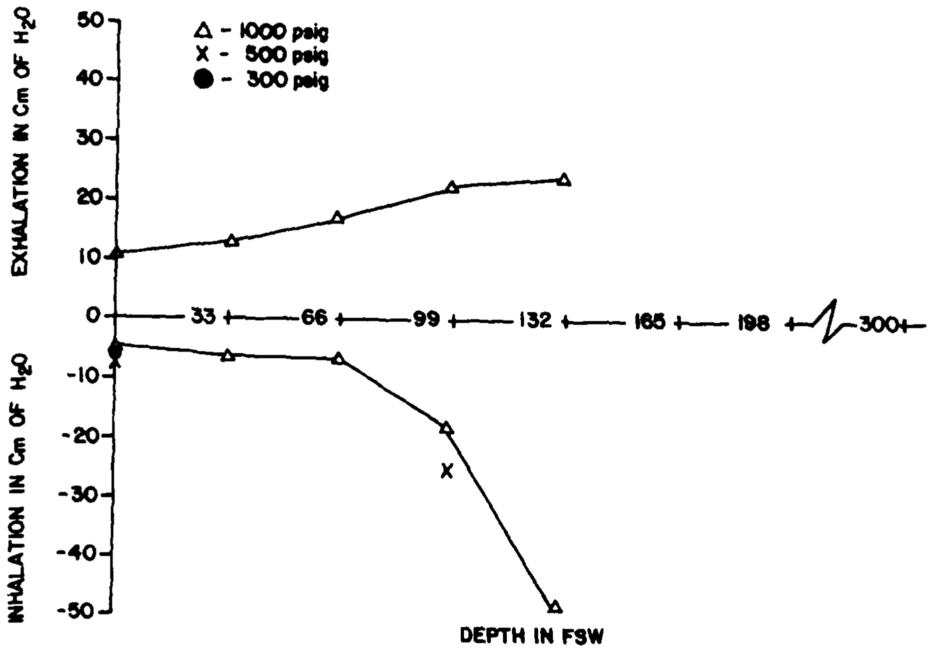

Figure 8A-5. Sherwood Selpac SRB-2000
Breathing resistance vs. depth at 90 RMV

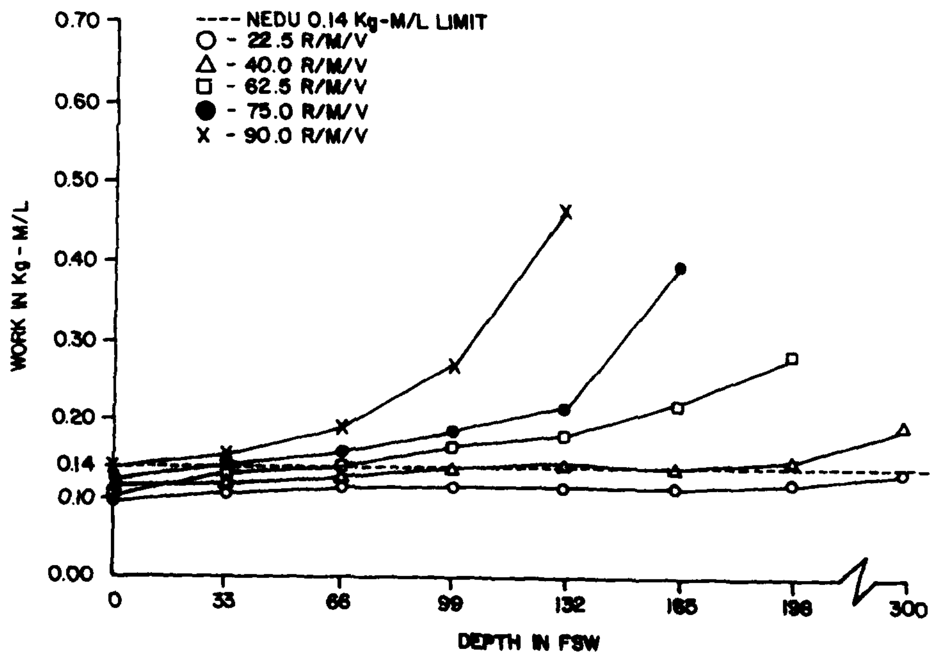

Figure 8A-6. Sherwood Selpac SRB-2000
Breathing work vs. depth at 1000 psig supply pressure

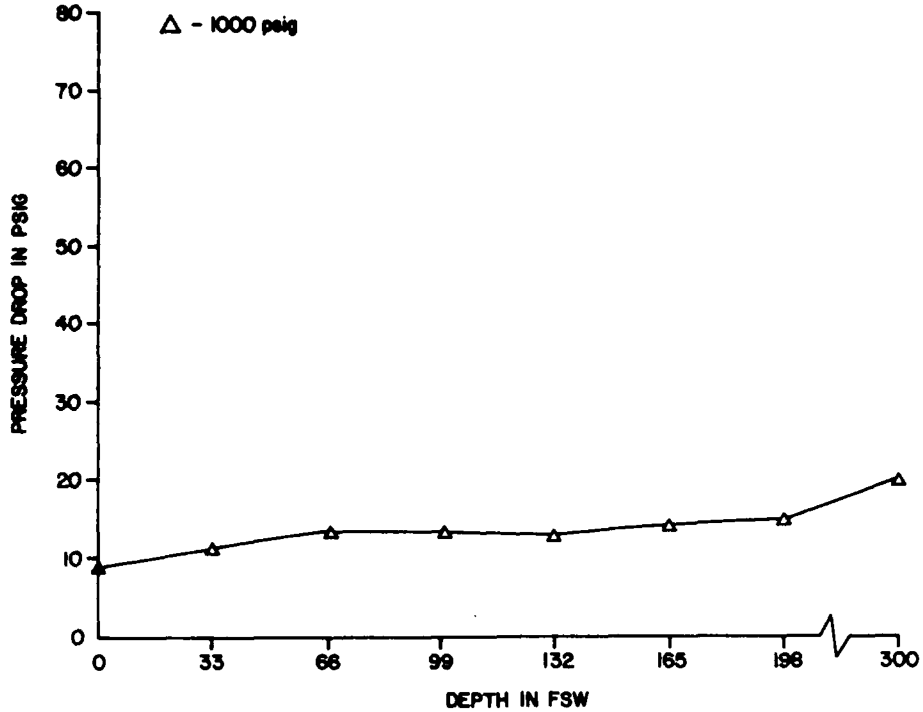

Figure 8A-7. Sherwood Selpac SRB-2000
First stage pressure drop vs. depth at 22.5 RMV

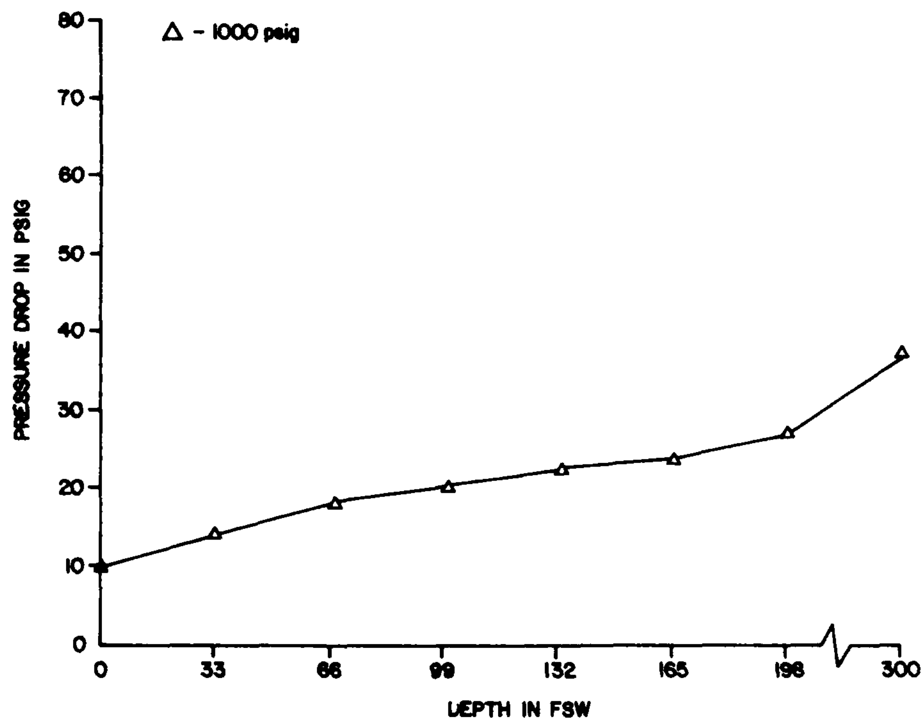

Figure 8A-8. Sherwood Selpac SRB-2000
First stage pressure drop vs. depth at 40 RMV

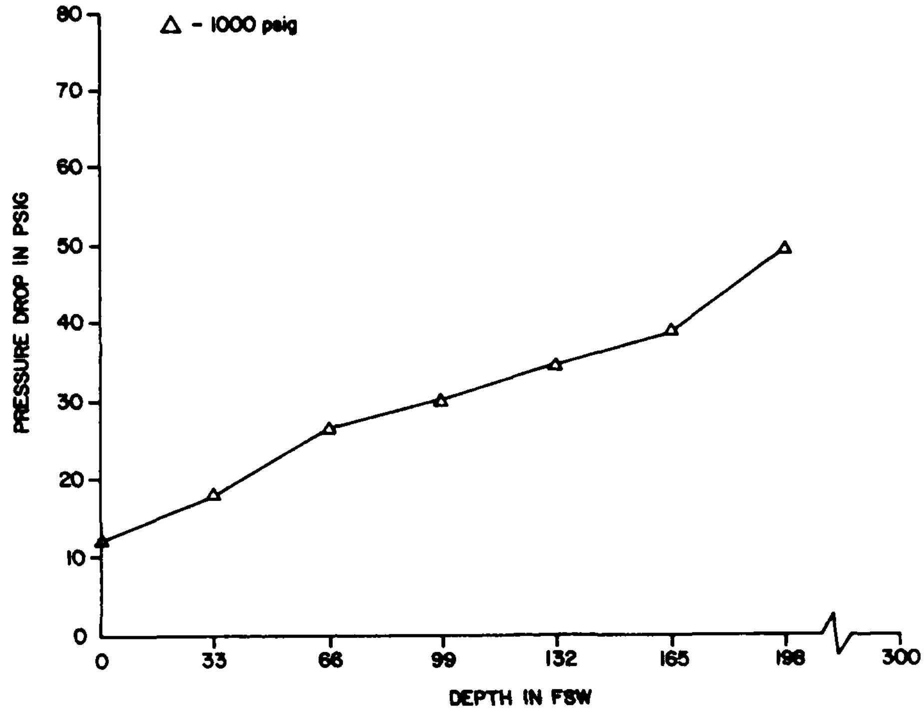

Figure 8A-9. Sherwood Selpac SRB-2000
First stage pressure drop vs. depth at 62.5 RMV

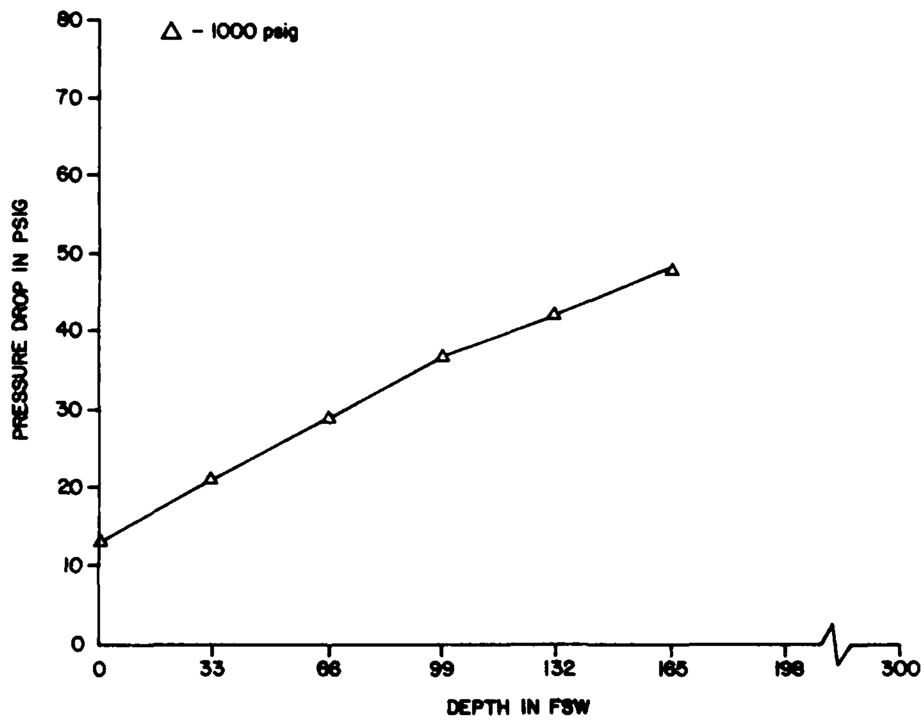

Figure 8A-10. Sherwood Selpac SRB-2000
First stage pressure drop vs. depth at 75 RMV

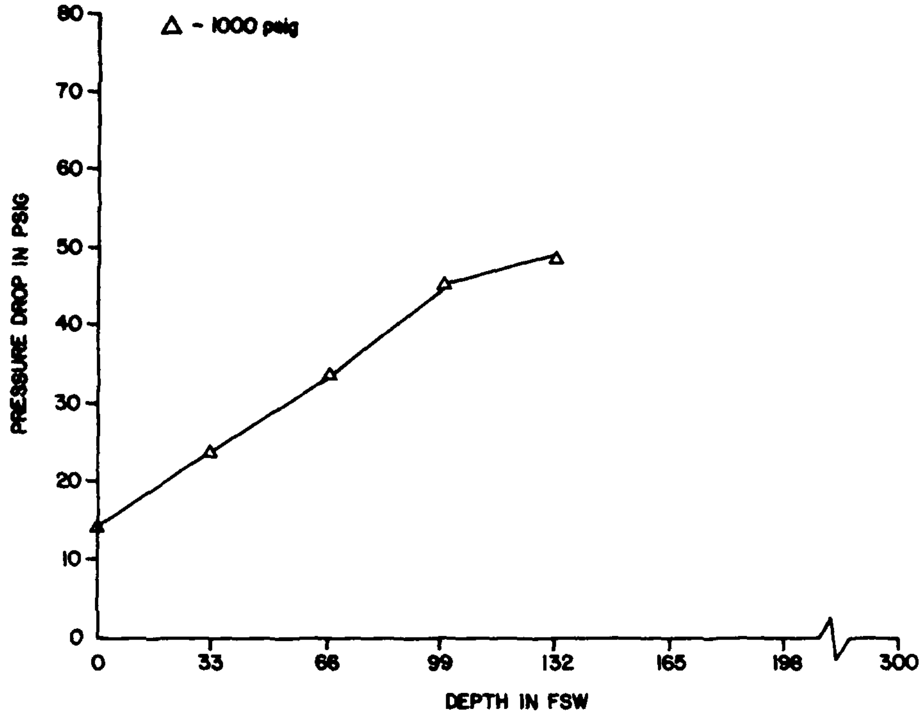

Figure 8A-11. Sherwood Selpac SRB-2000
First stage pressure drop vs. depth at 90 RMV

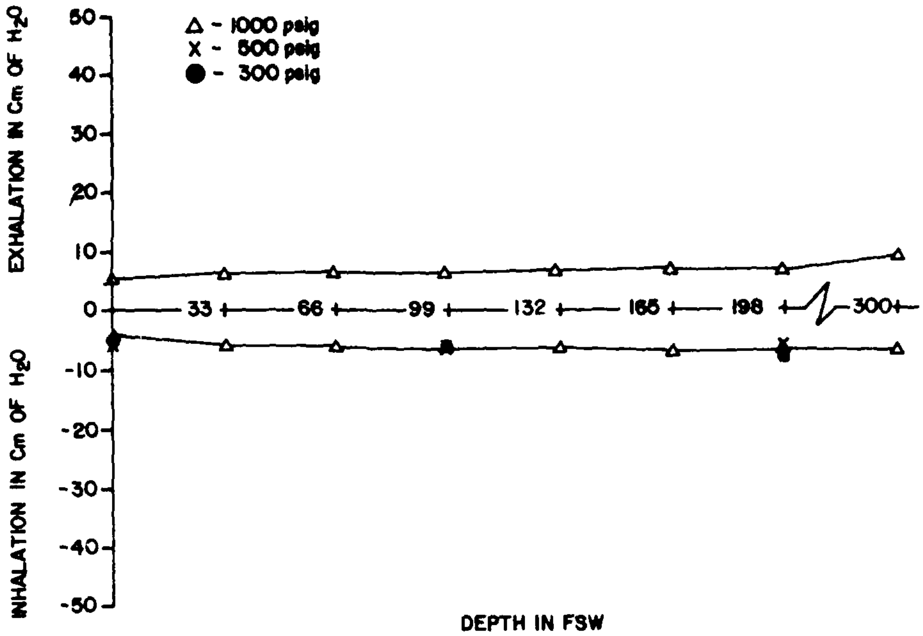

Figure 8B-1. Sherwood Selpac SRB-3100
Breathing resistance vs. depth at 22.5 RMV

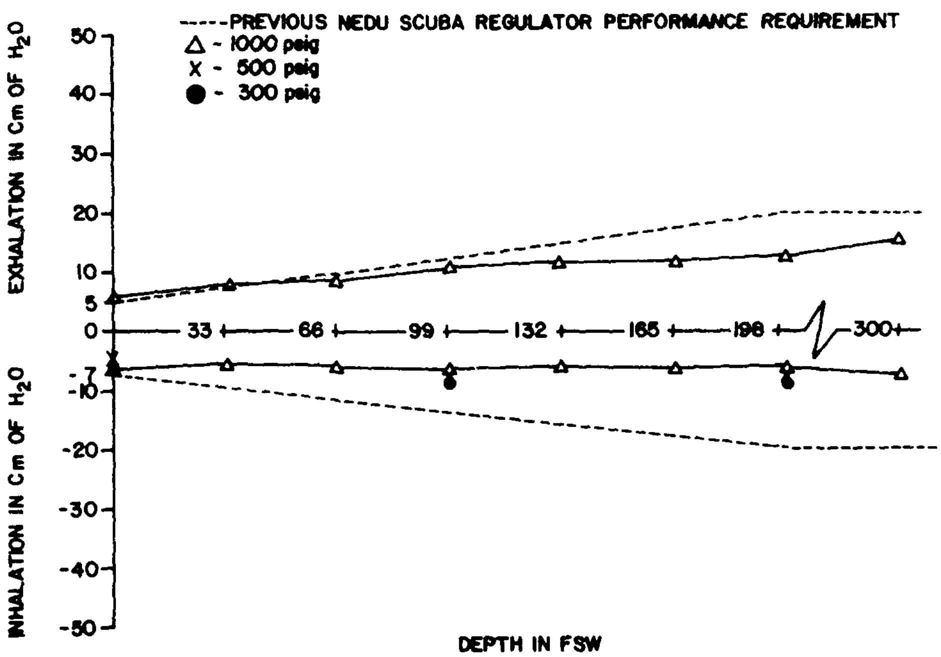

Figure 8B-2. Sherwood Selpac SRB-3100
Breathing resistance vs. depth at 40 RMV

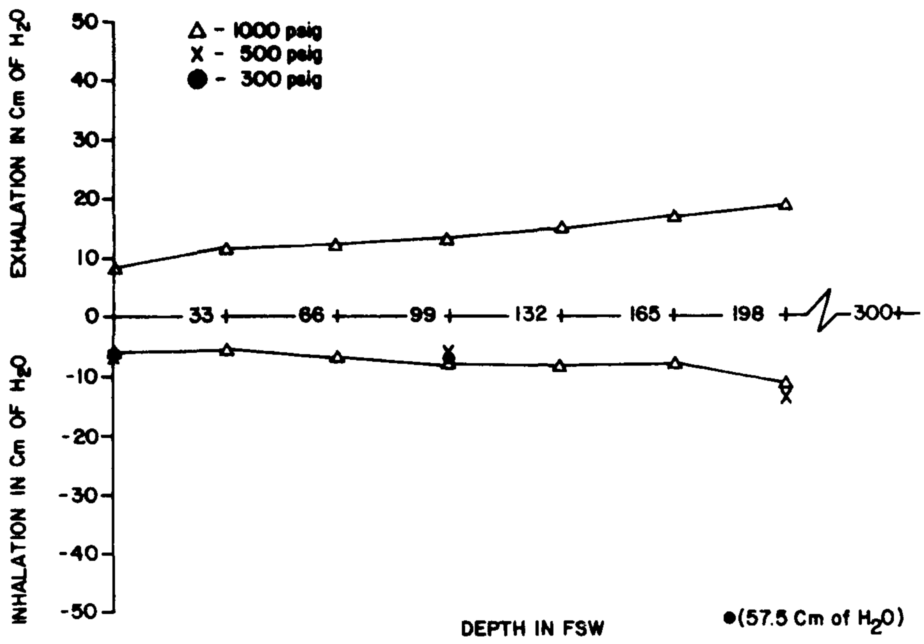

Figure 8B-3. Sherwood Selpac SRB-3100
Breathing resistance vs. depth at 62.5 RMV

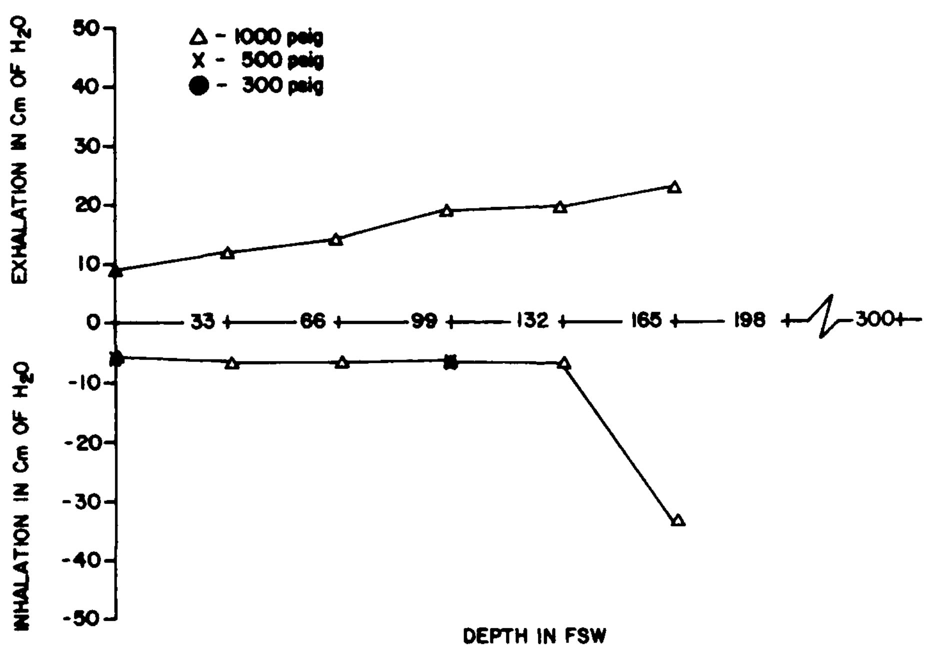

Figure 8B-4. Sherwood Selpac SRB-3100
Breathing resistance vs. depth at 75 RMV

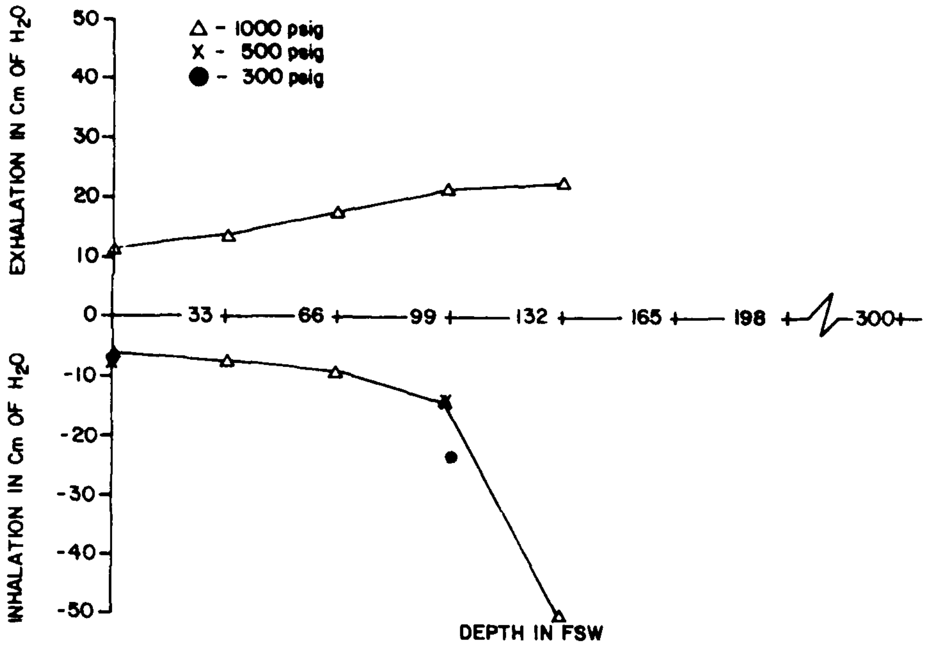

Figure 8B-5. Sherwood Selpac SRB-3100
Breathing resistance vs. depth at 90 RMV

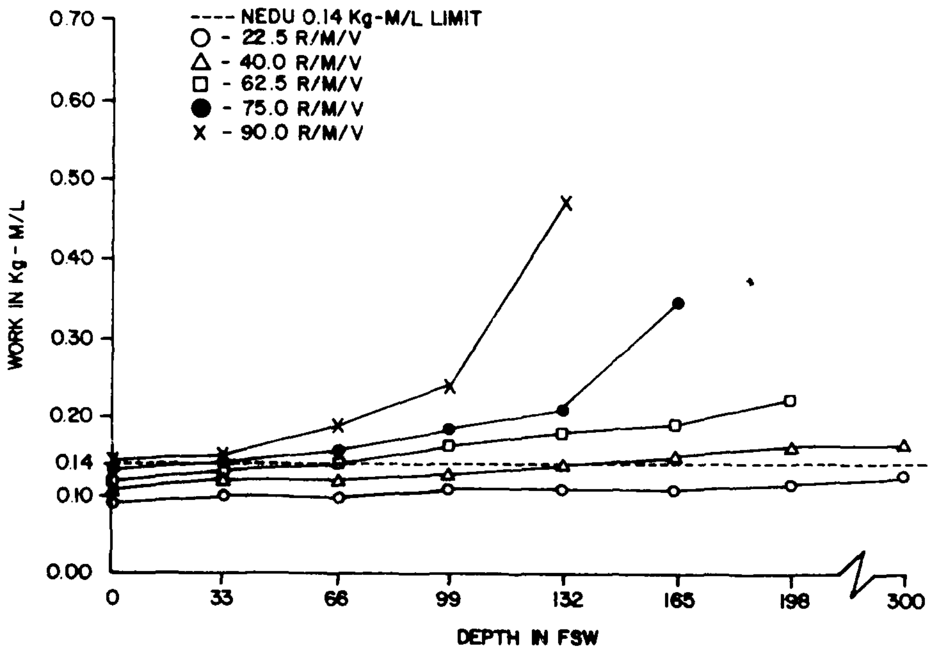

Figure 8B-6. Sherwood Selpac SRB-3100
Breathing work vs. depth at 1000 psig supply pressure

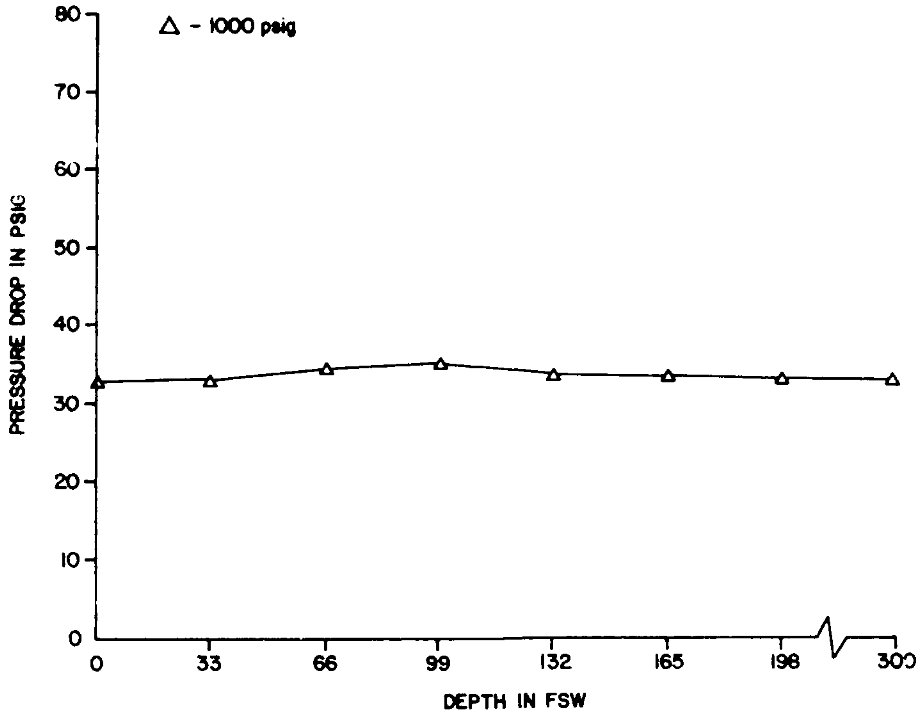

Figure 8B-7. Sherwood Selpac SRB-3100
First stage pressure drop vs. depth at 22.5 RMV

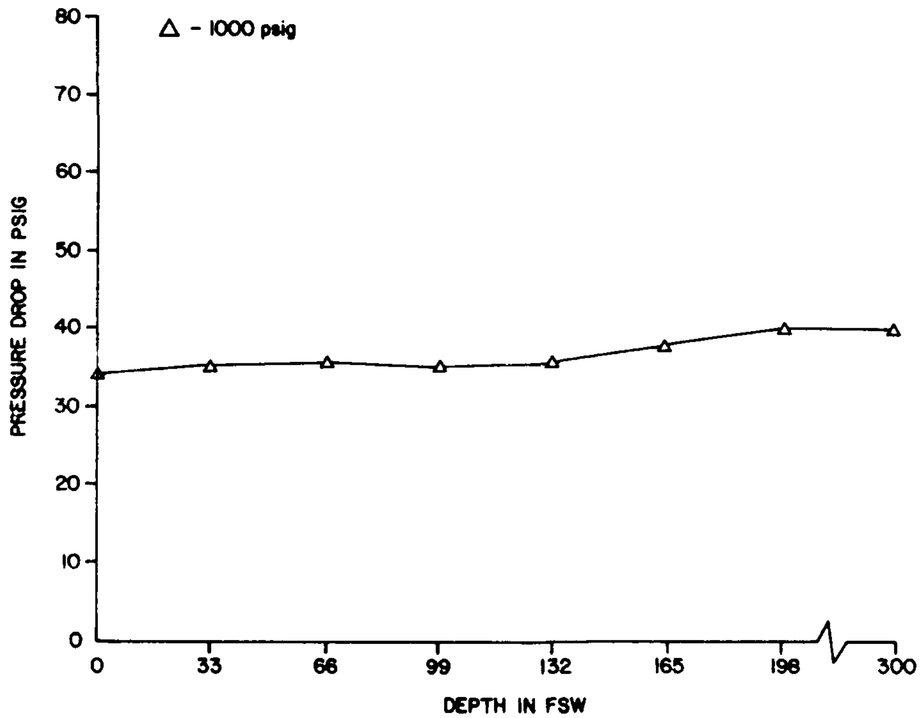

Figure 8B-8. Sherwood Selpac SRB-3100
First stage pressure drop vs. depth at 40 RMV

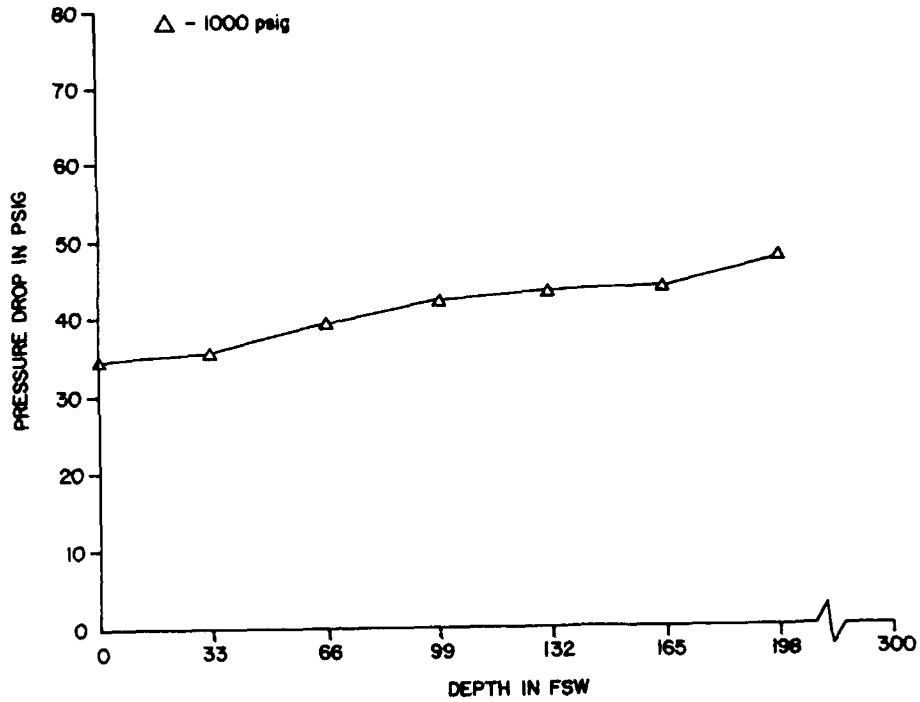

Figure 8B-9. Sherwood Selpac SRB-3100
First stage pressure drop vs. depth at 62.5 RMV

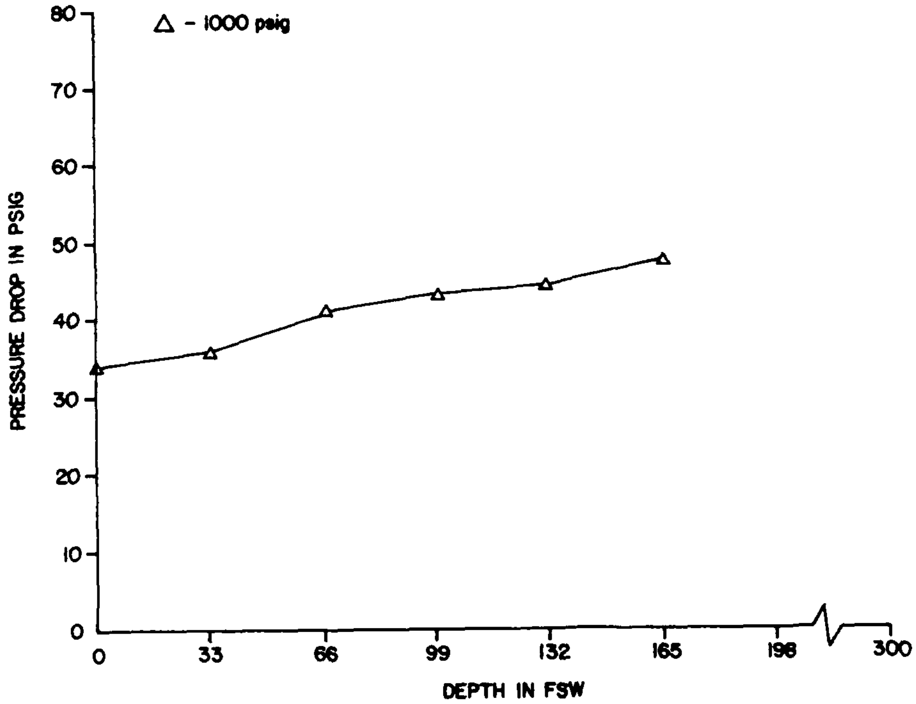

Figure 8B-10. Sherwood Selpac SRB-3100
First stage pressure drop vs. depth at 75 RMV

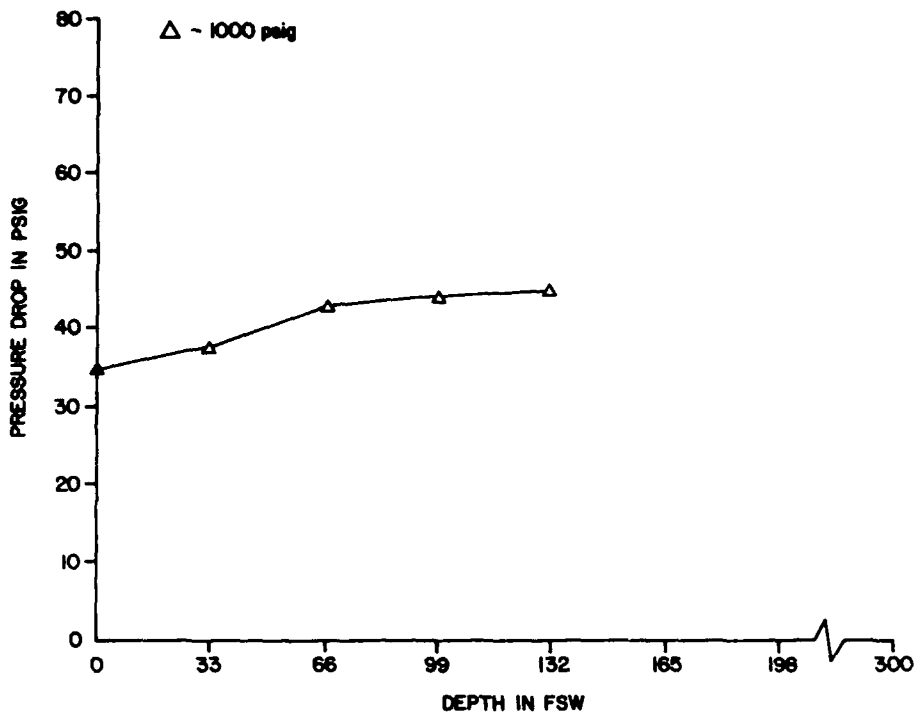

Figure 8B-11. Sherwood Selpac SRB-3100
First stage pressure drop vs. depth at 90 RMV

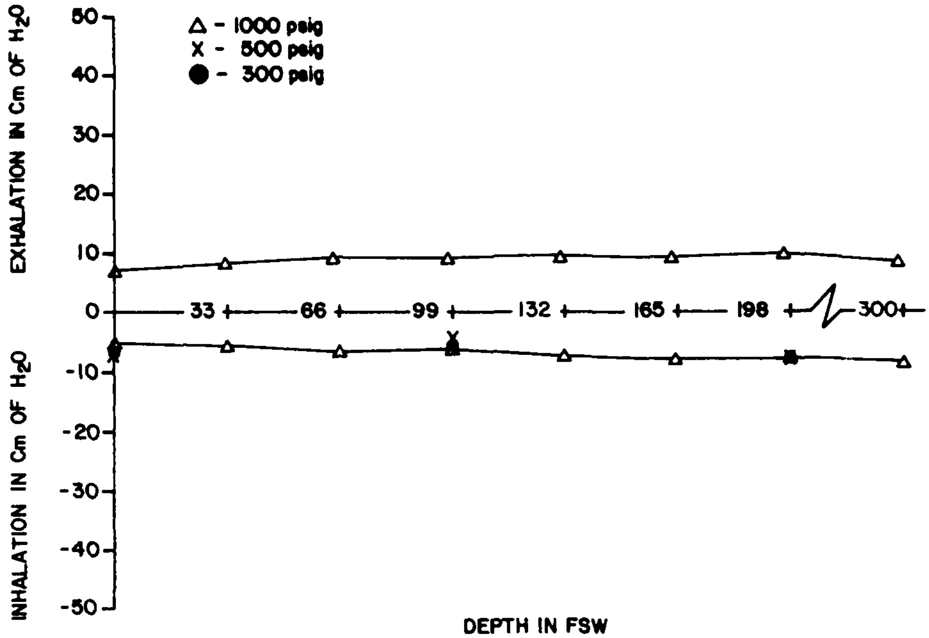

Figure 8C-1. Sherwood Selpac SRB-4100
Breathing resistance vs. depth at 22.5 RMV

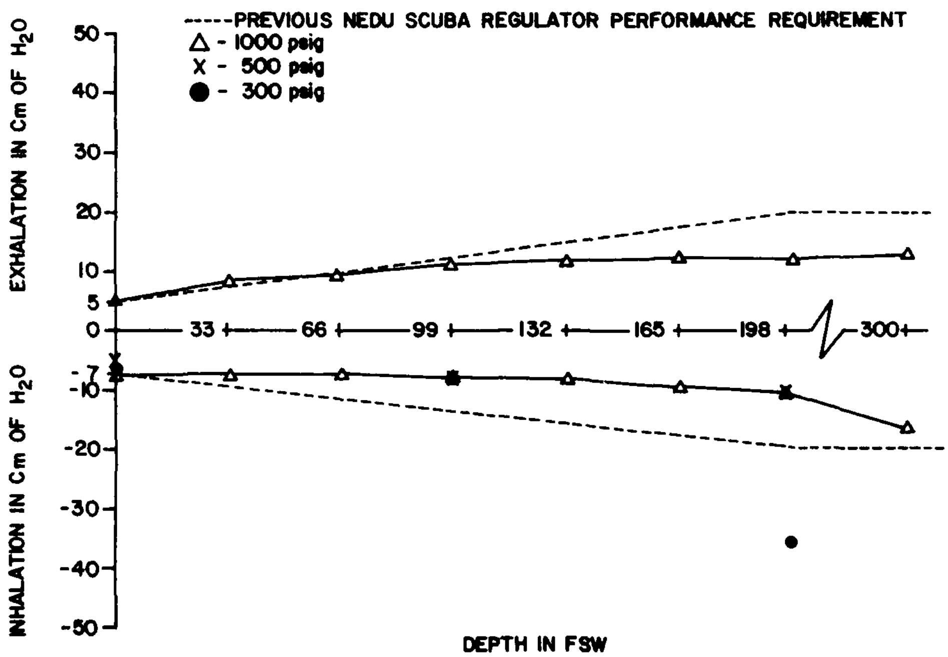

Figure 8C-2. Sherwood Selpac SRB-4100
Breathing resistance vs. depth at 40 RMV

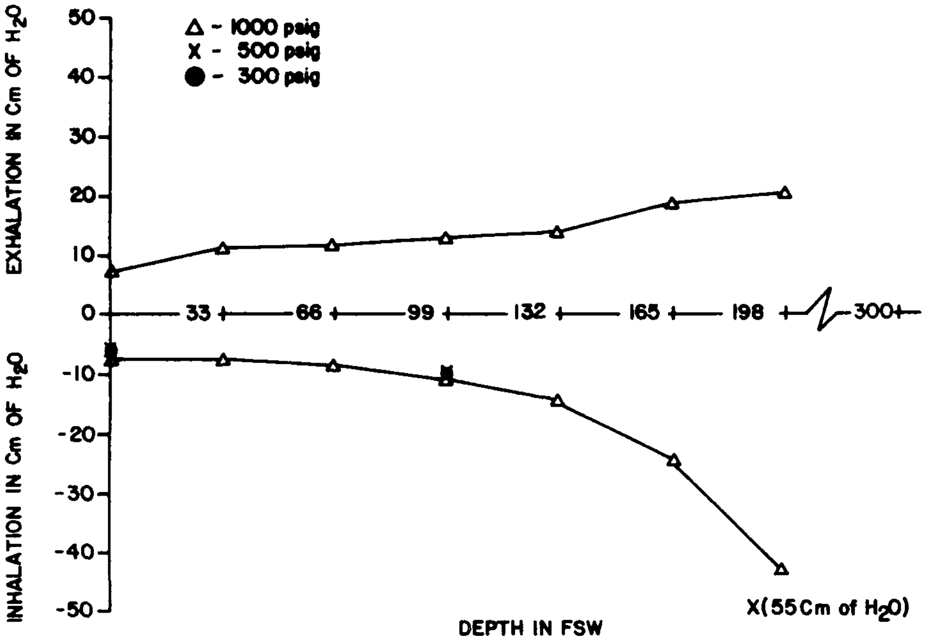

Figure 8C-3. Sherwood Selpac SRB-4100
Breathing resistance vs. depth at 62.5 RMV

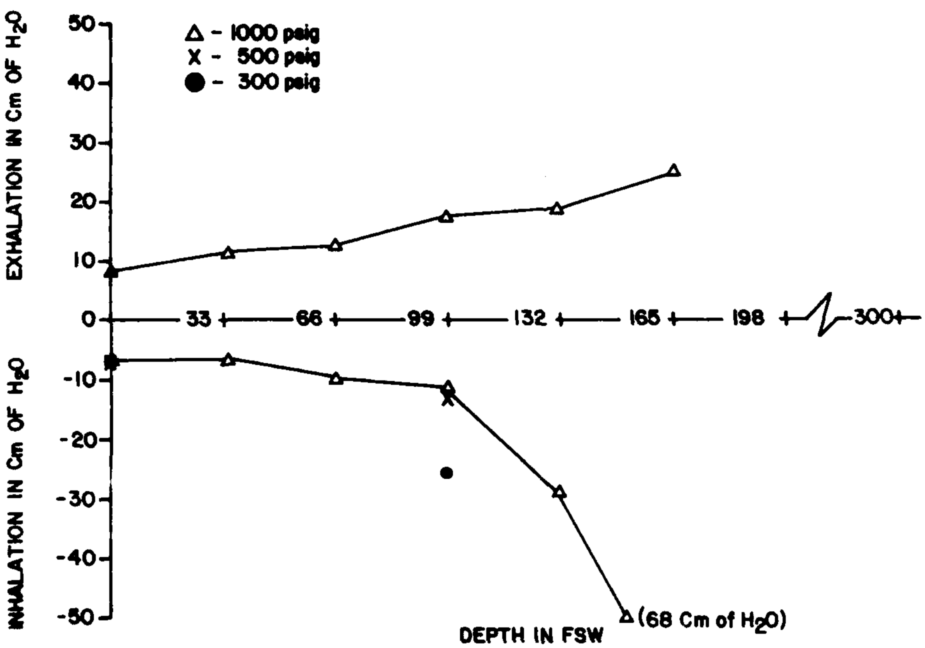

Figure 8C-4. Sherwood Selpac SRB-4100
Breathing resistance vs. depth at 75 RMV

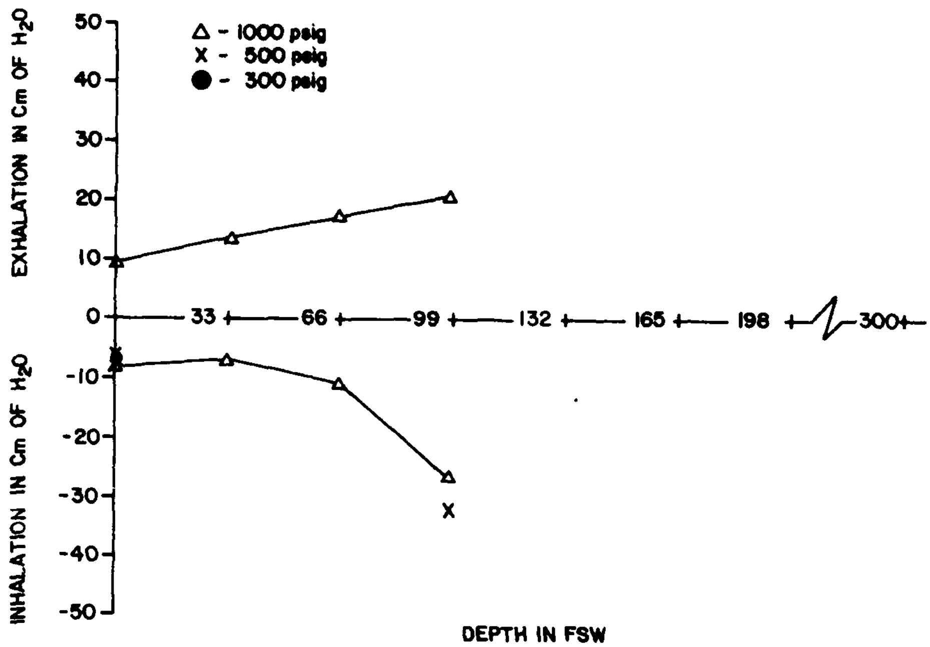

Figure 8C-5. Sherwood Selpac SRB-4100
Breathing resistance vs. depth at 90 RMV

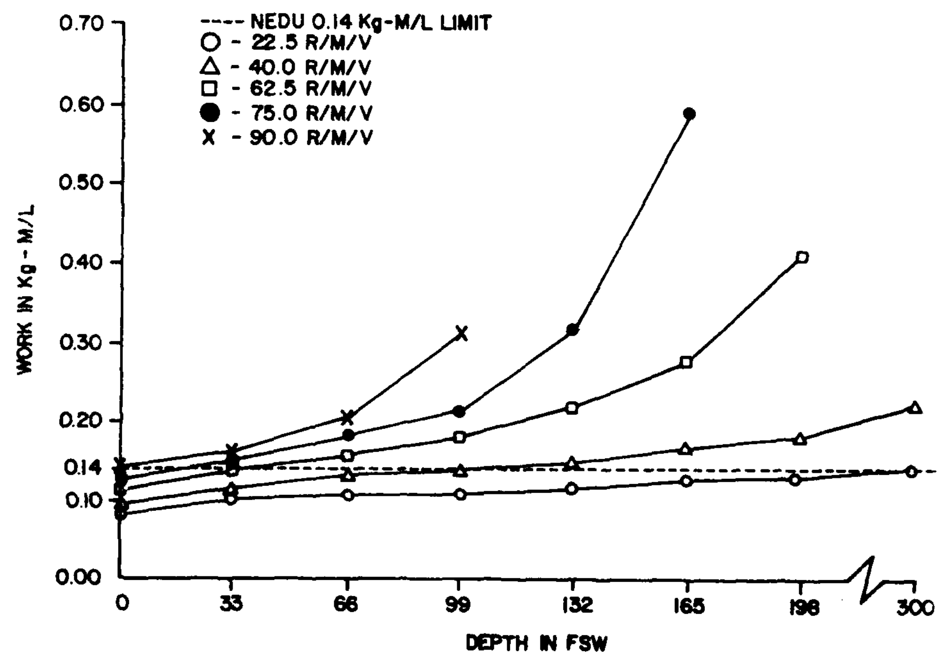

Figure 8C-6. Sherwood Selpac SRB-4100
Breathing work vs. depth at 1000 psig supply pressure

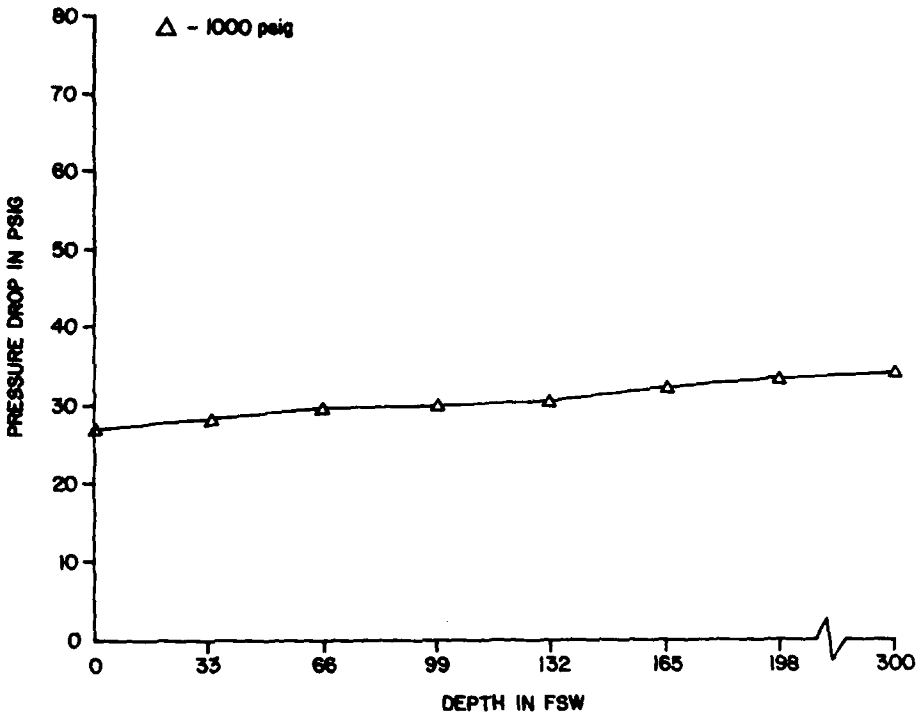

Figure 8C-7. Sherwood Selpac SRB-4100
First stage pressure drop vs. depth at 22.5 RMV

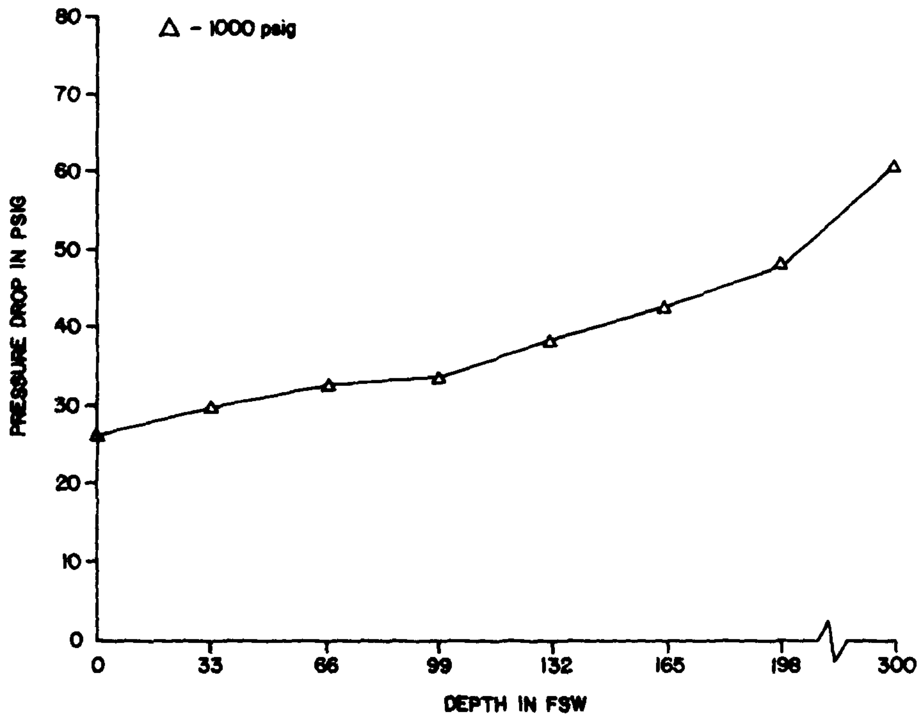

Figure 8C-8. Sherwood Selpac SRB-4100
First stage pressure drop vs. depth at 40 RMV

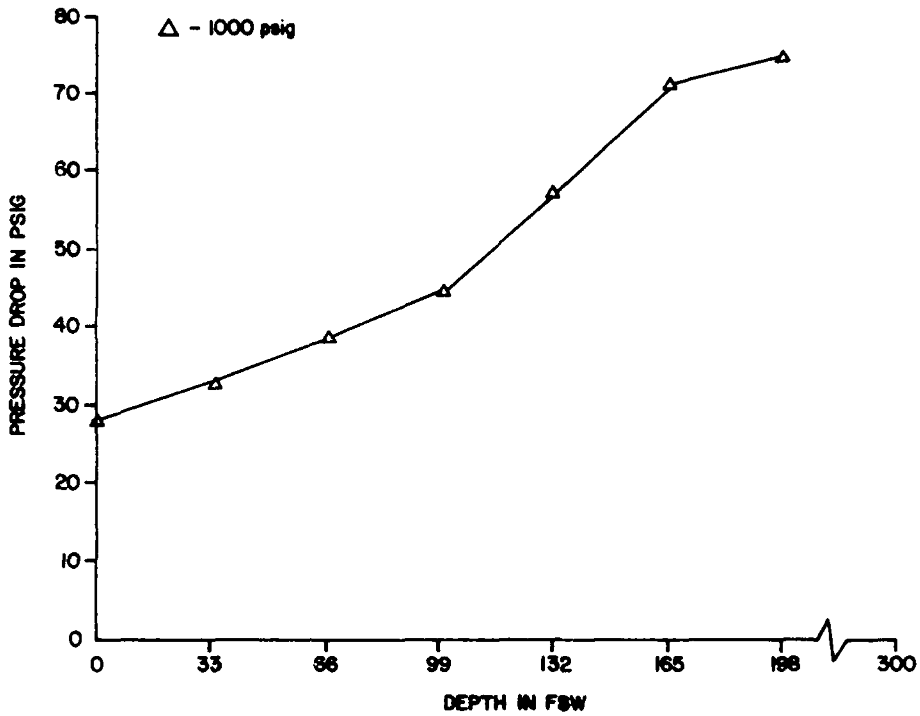

Figure 8C-9. Sherwood Selpac SRB-4100
First stage pressure drop vs. depth at 62.5 RMV

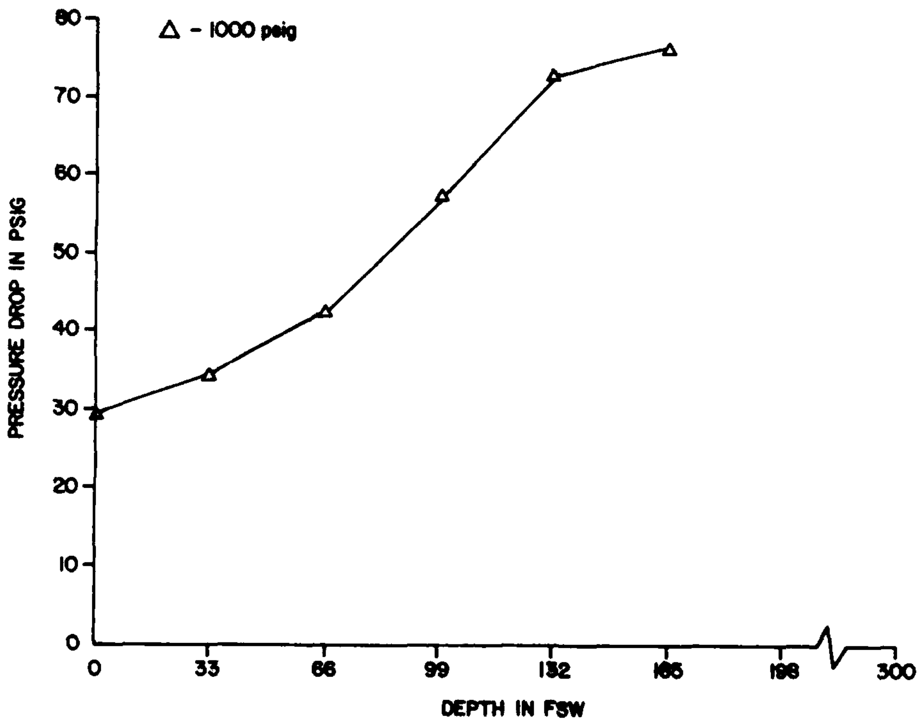

Figure 8C-10. Sherwood Selpac SRB-4100
First stage pressure drop vs. depth at 75 RMV

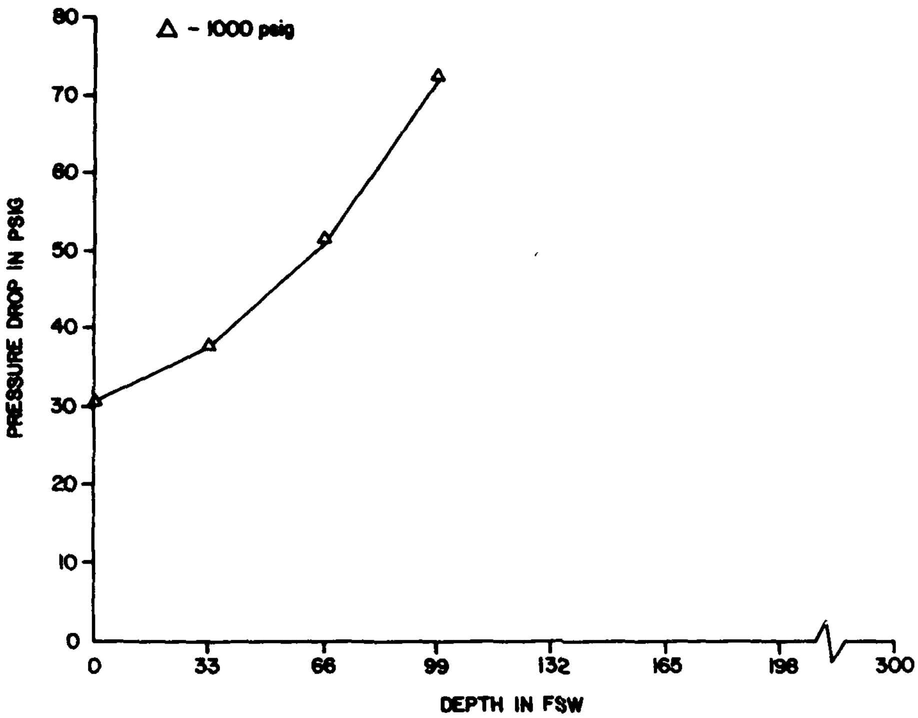

Figure 8C-11. Sherwood Selpac SRB-4100
First stage pressure drop vs. depth at 90 RMV

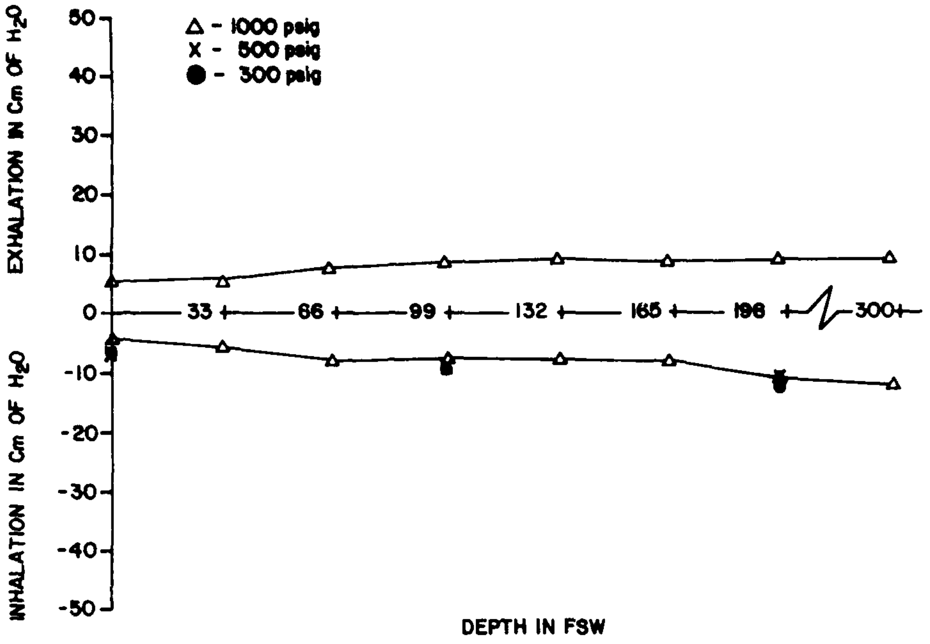

Figure 9A-1. Sportsways WL-200
Breathing resistance vs. depth at 22.5 RMV

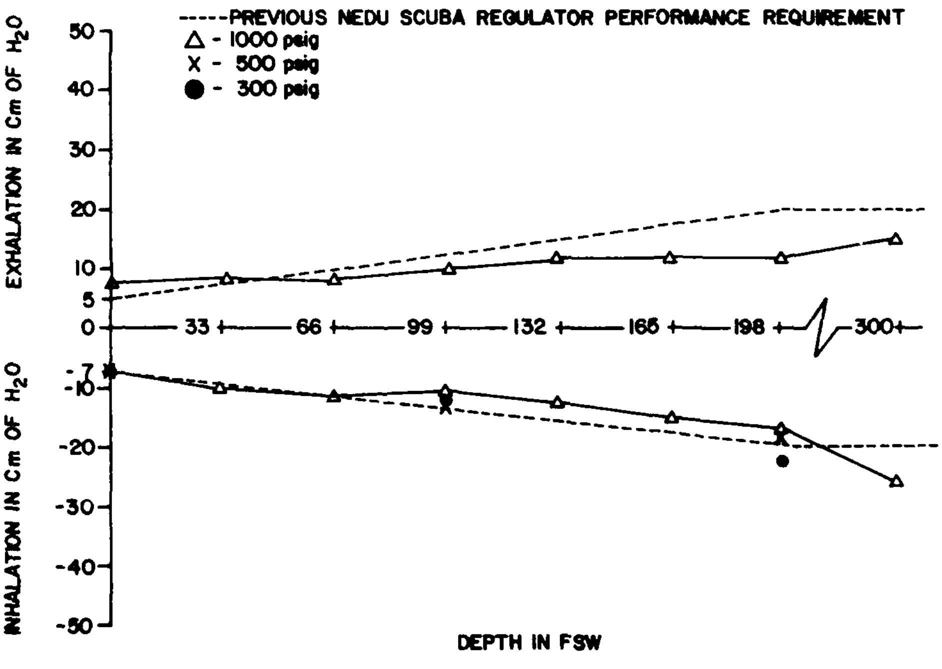

Figure 9A-2. Sportsways WL-200
Breathing resistance vs. depth at 40 RMV

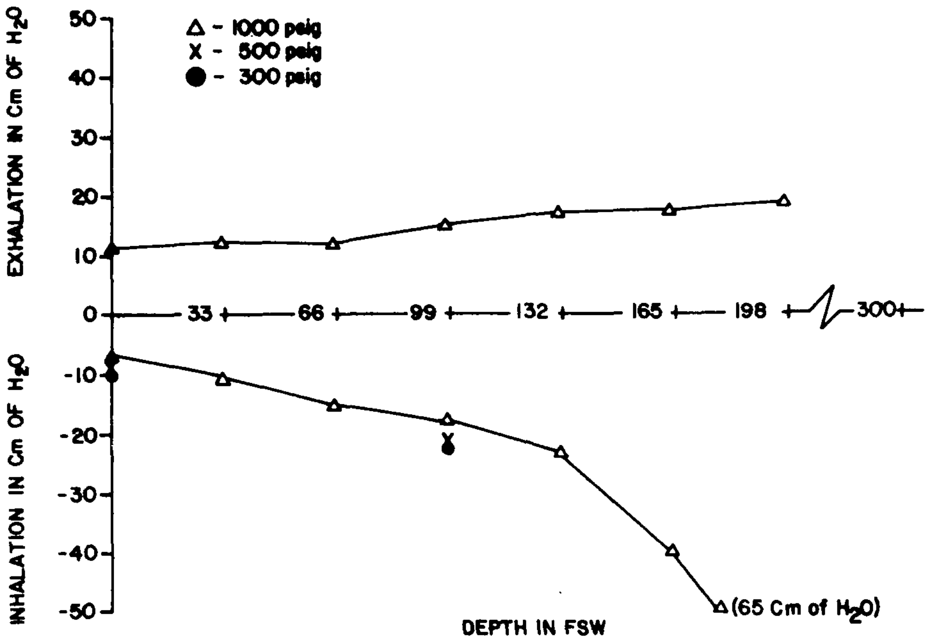

Figure 9A-3. Sportsways WL-200
Breathing resistance vs. depth at 62.5 RMV

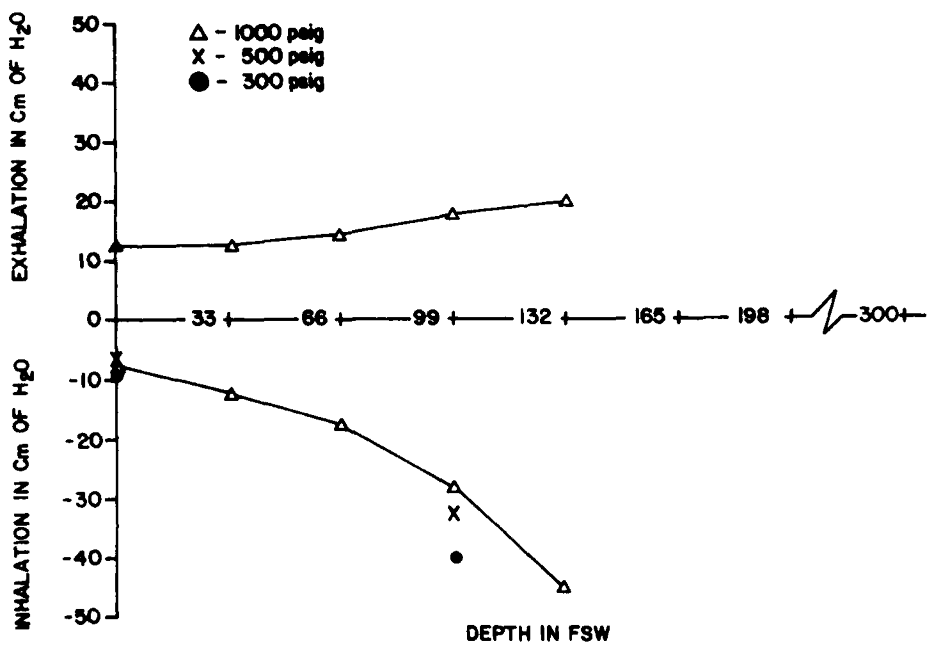

Figure 9A-4. Sportsways WL-200
Breathing resistance vs. depth at 75 RMV

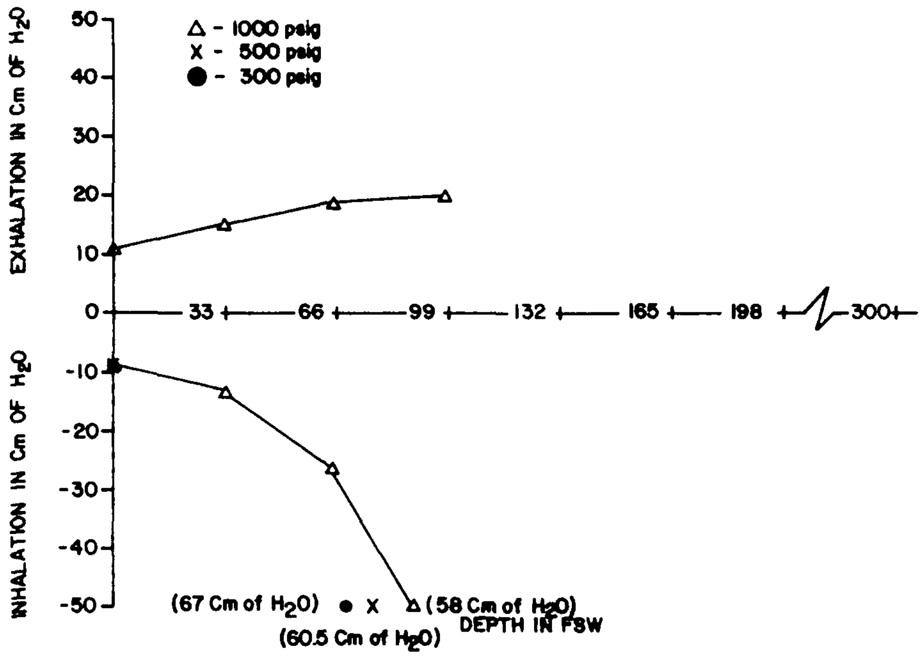

Figure 9A-5. Sportsways WL-200
Breathing resistance vs. depth at 90 RMV

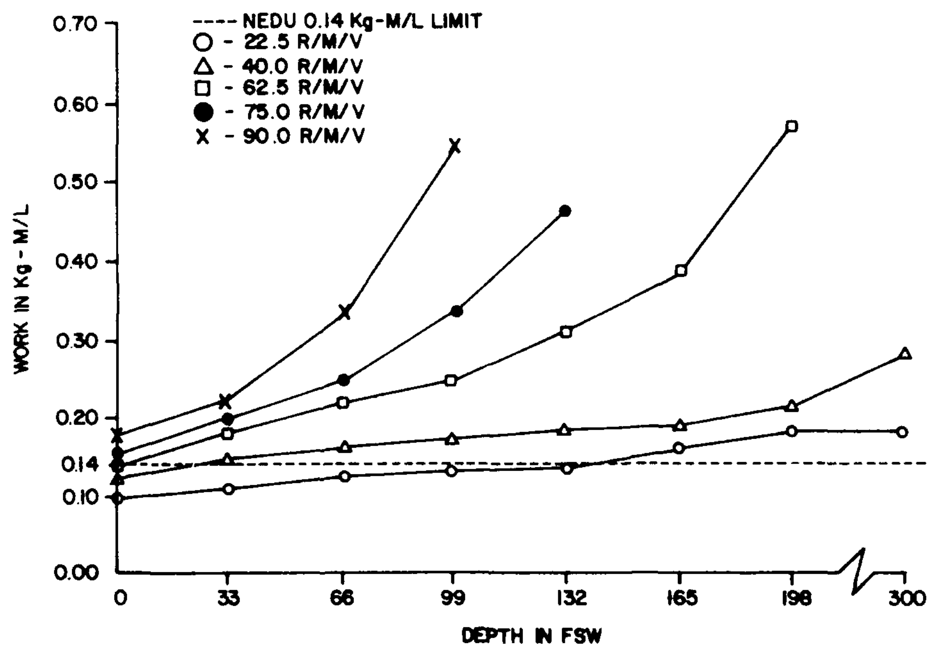

Figure 9A-6. Sportsways WL-200
Breathing work vs. depth at 1000 psig supply pressure

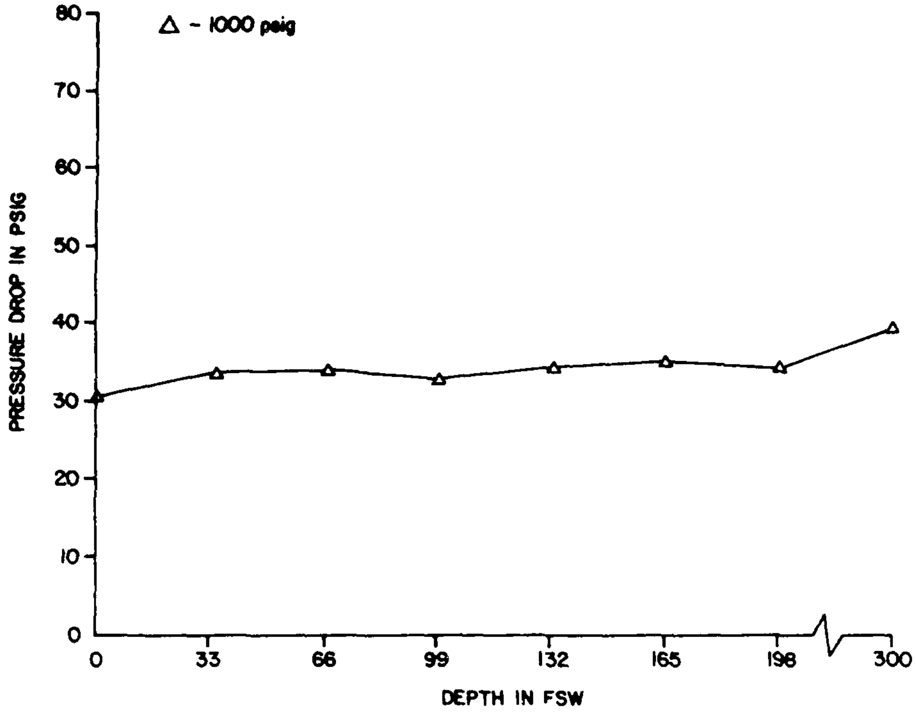

Figure 9A-7. Sportsways WL-200
First stage pressure drop vs. depth at 22.5 RMV

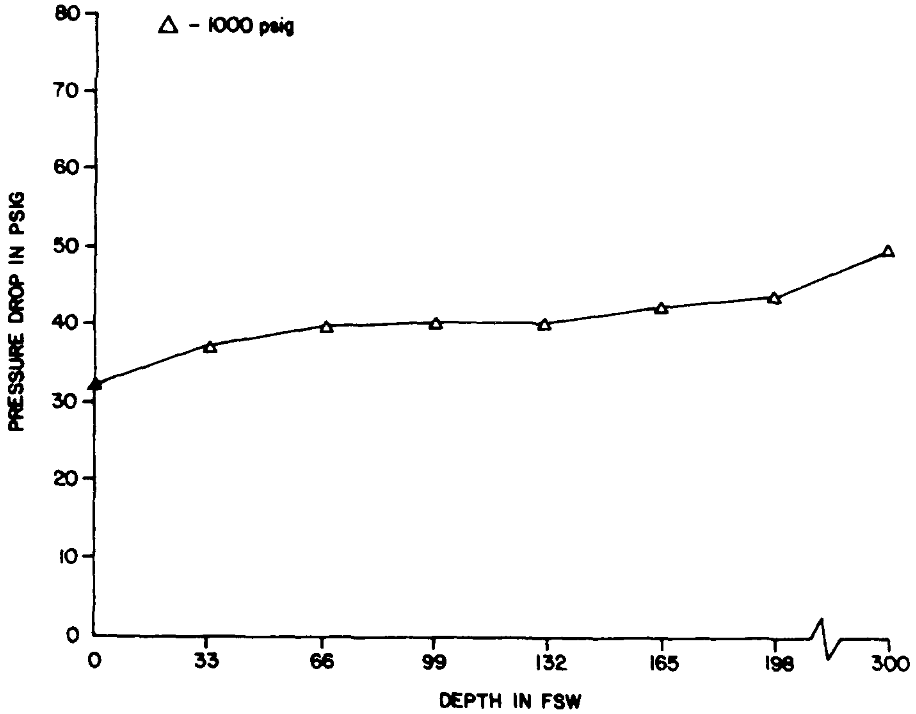

Figure 9A-8. Sportsways WL-200
First stage pressure drop vs. depth at 40 RMV

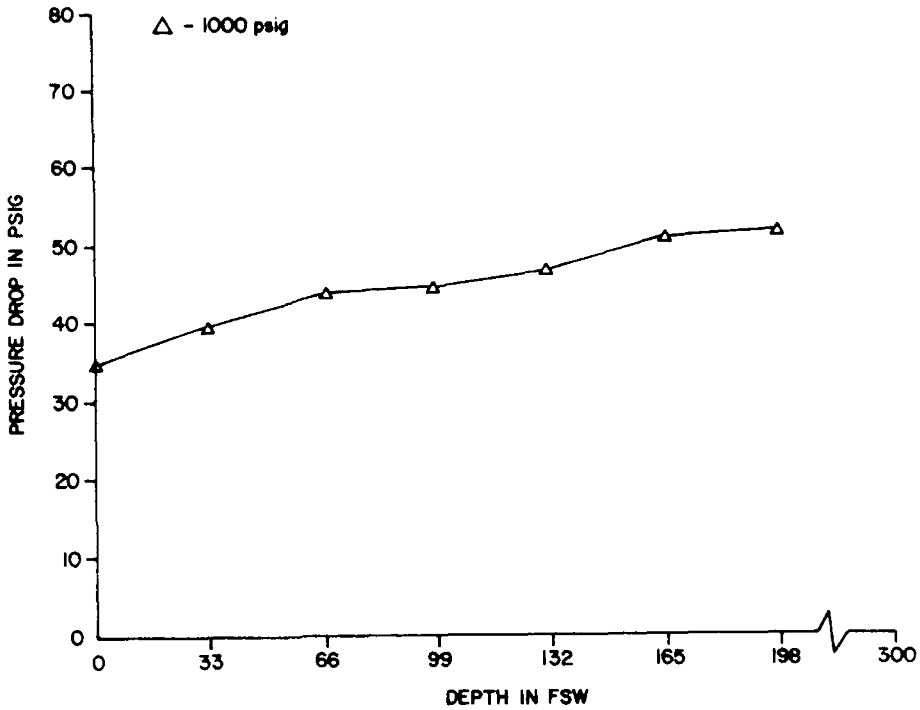

Figure 9A-9. Sportsways WL-200
First stage pressure drop vs. depth at 62.5 RMV

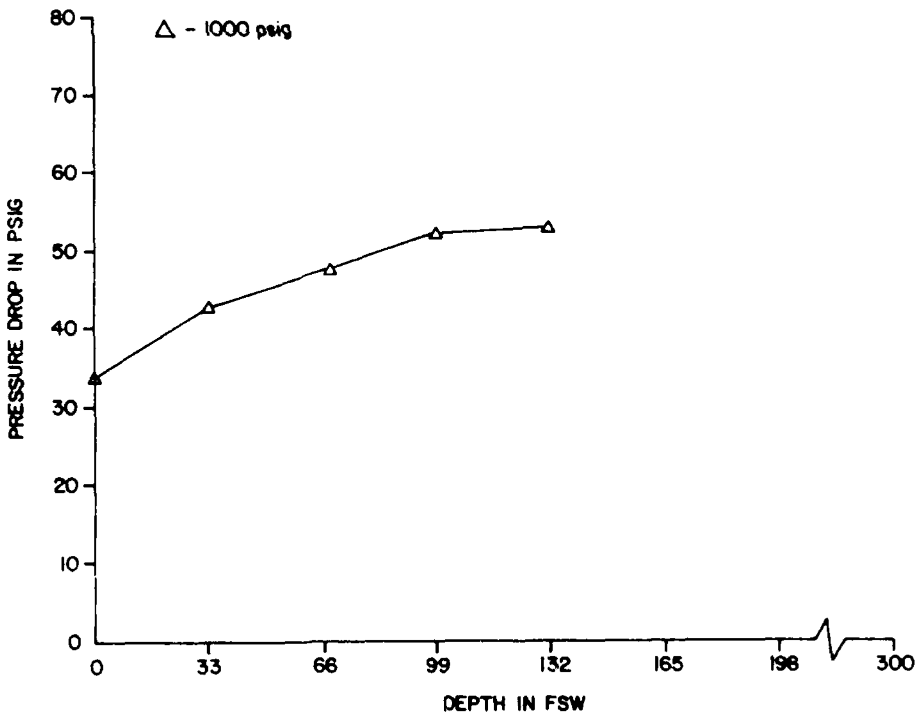

Figure 9A-10. Sportsways WL-200
First stage pressure drop vs. depth at 75 RMV

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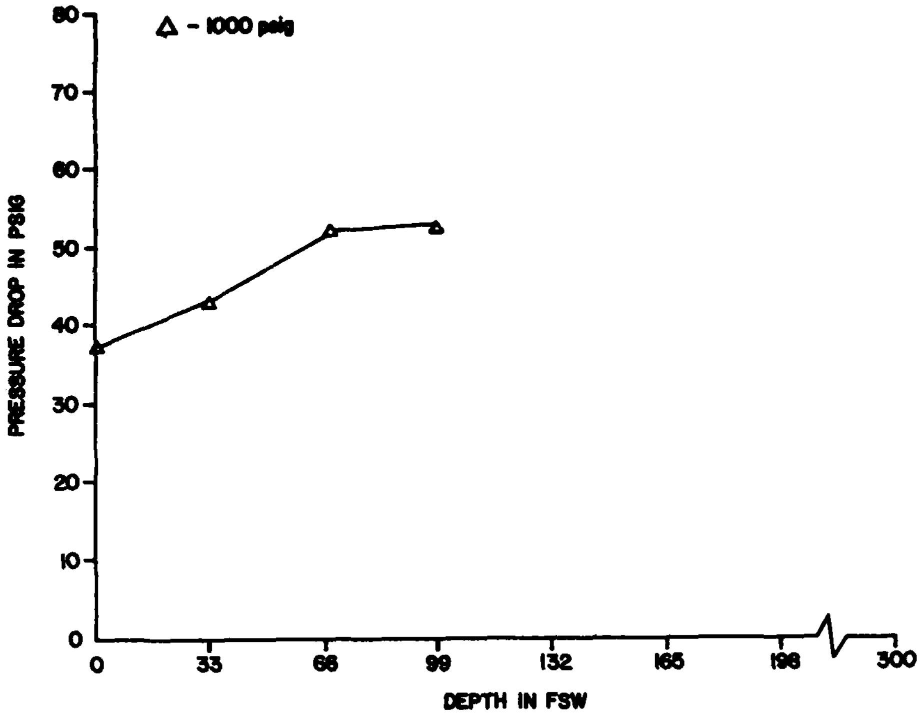

Figure 9A-11. Sportsways WL-200
First stage pressure drop vs. depth at 90 RMV

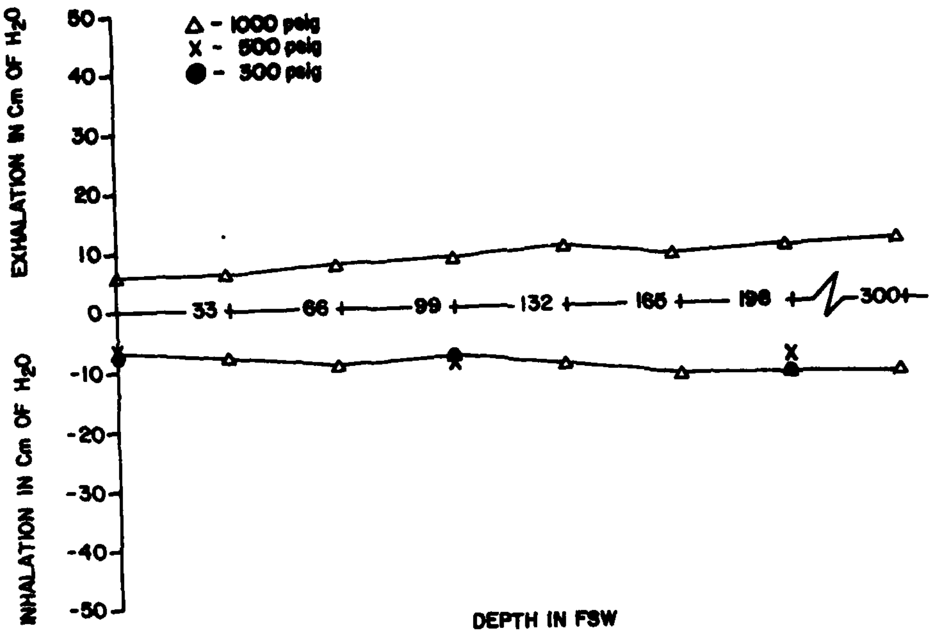

Figure 9B-1. Sportsways W-600 Hydronaut
Breathing resistance vs. depth at 22.5 RMV

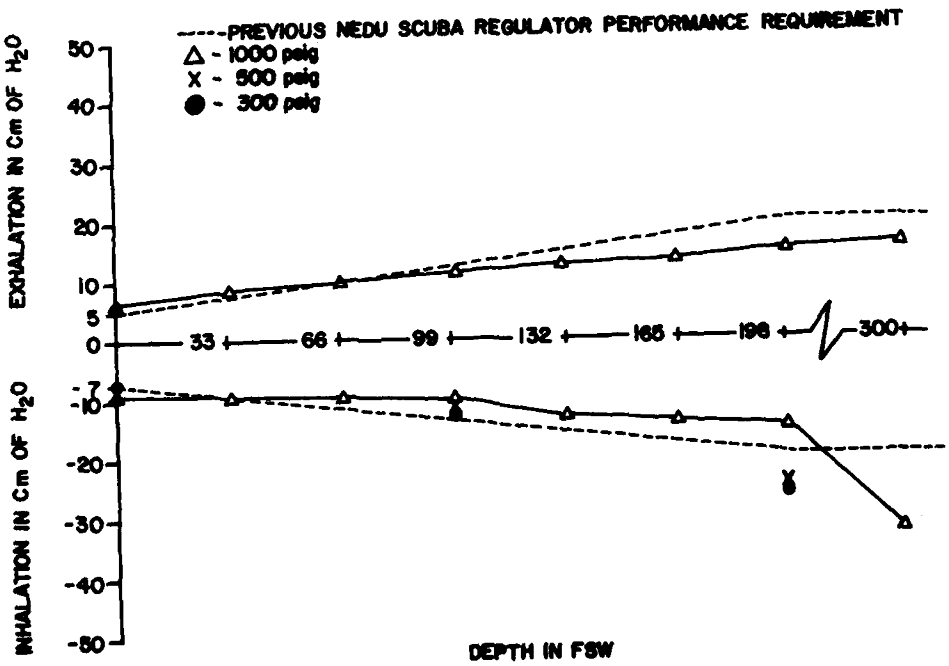

Figure 9B-2. Sportsways W-600 Hydronaut
Breathing resistance vs. depth at 40 RMV

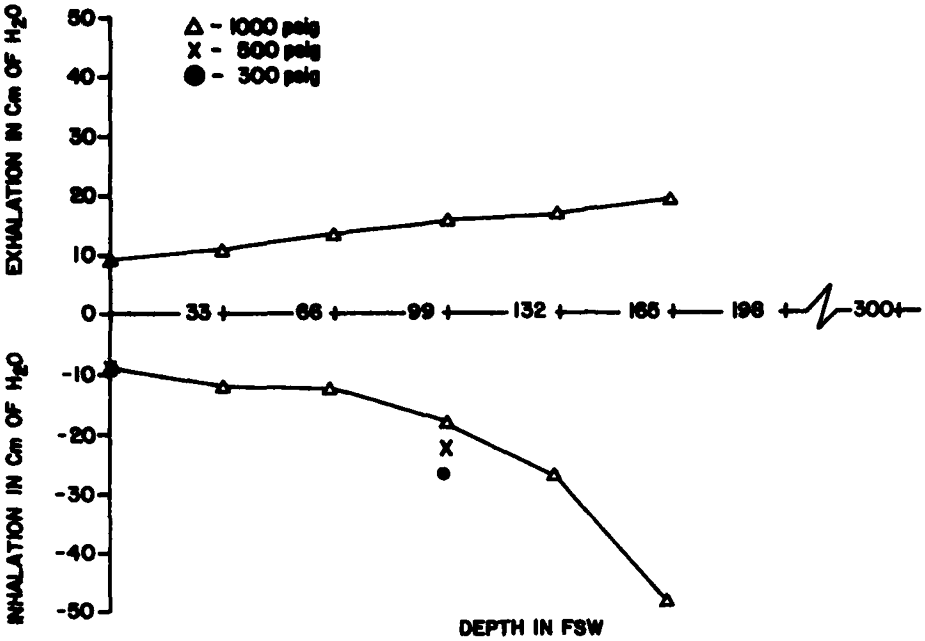

Figure 9B-3. Sportsways W-600 Hydronaut
Breathing resistance vs. depth at 62.5 RMV

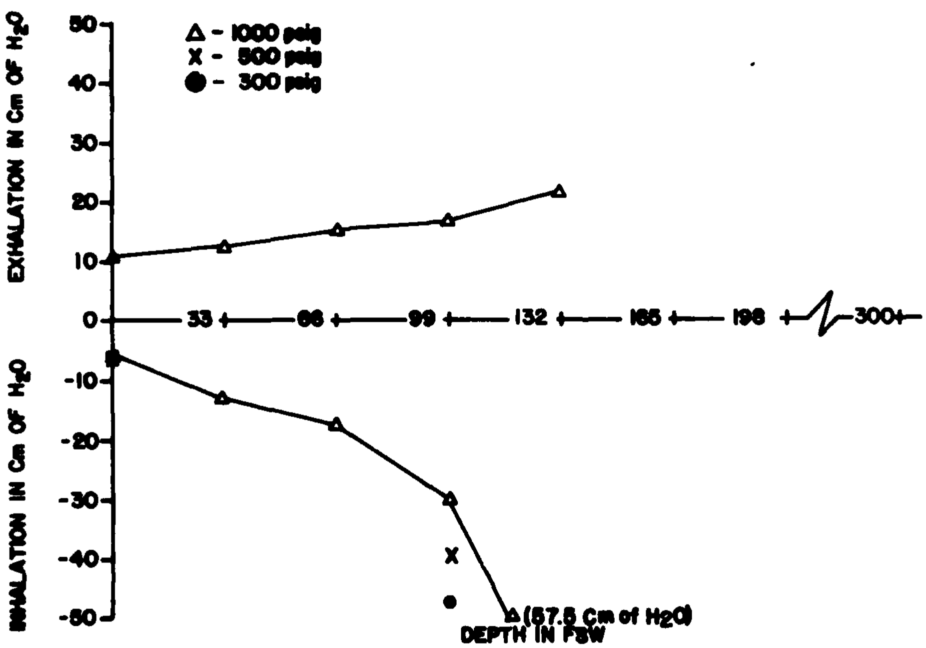

Figure 9B-4. Sportsways W-600 Hydronaut
Breathing resistance vs. depth at 75 RMV

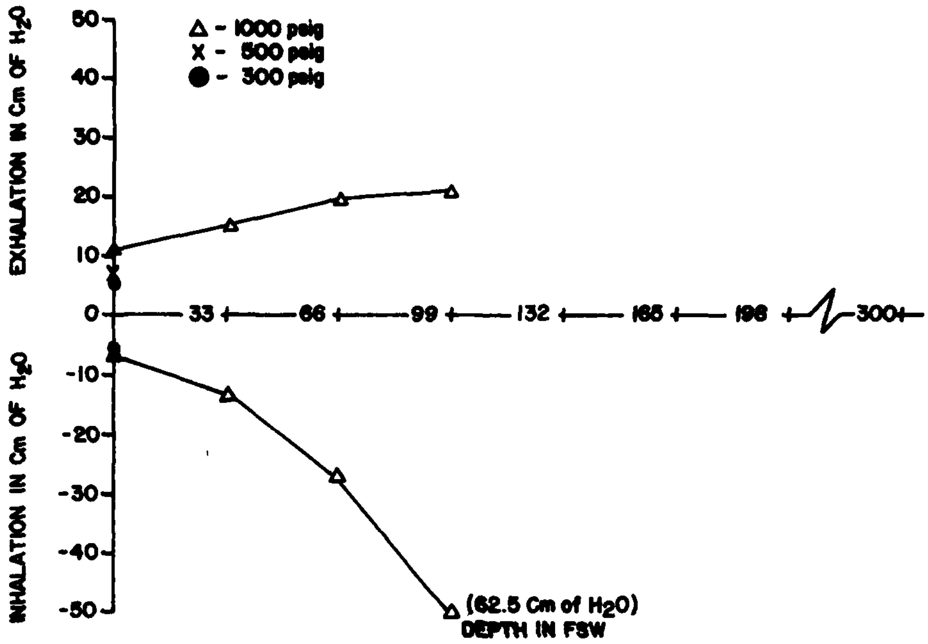

Figure 9B-5. Sportsways W-600 Hydronaut
Breathing resistance vs. depth at 90 RMV

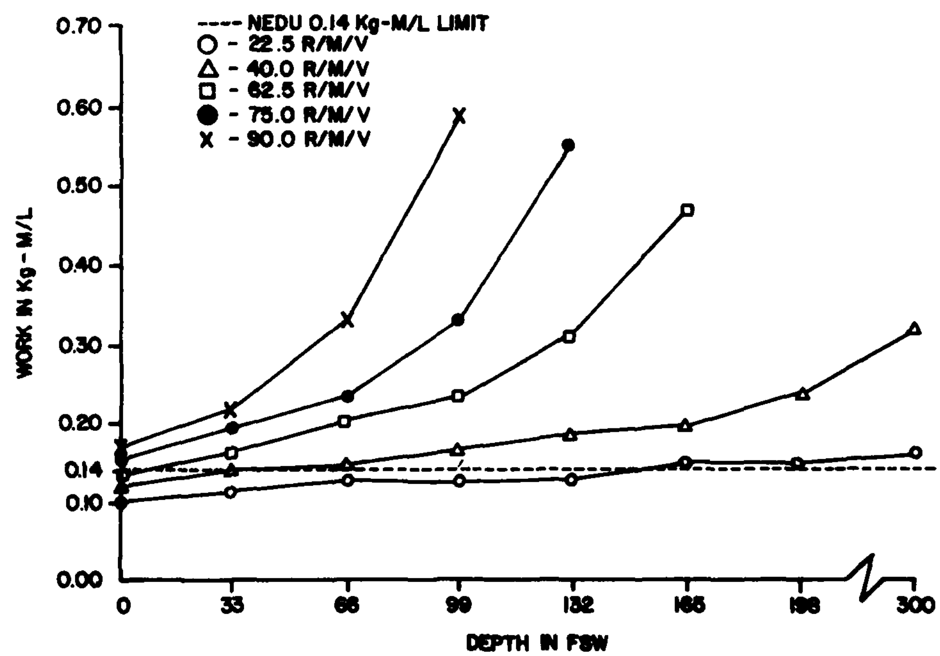

Figure 9B-6. Sportsways W-600 Hydronaut
Breathing work vs. depth at 1000 psig supply pressure

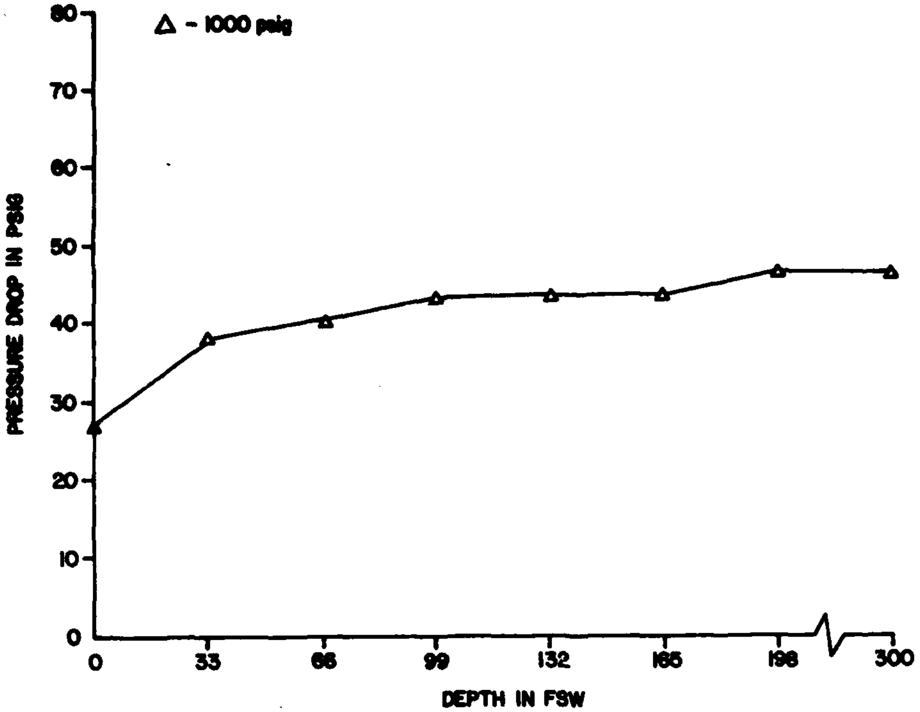

Figure 9B-7. Sportsways W-600 Hydronaut
First stage pressure drop vs. depth at 22.5 RMV

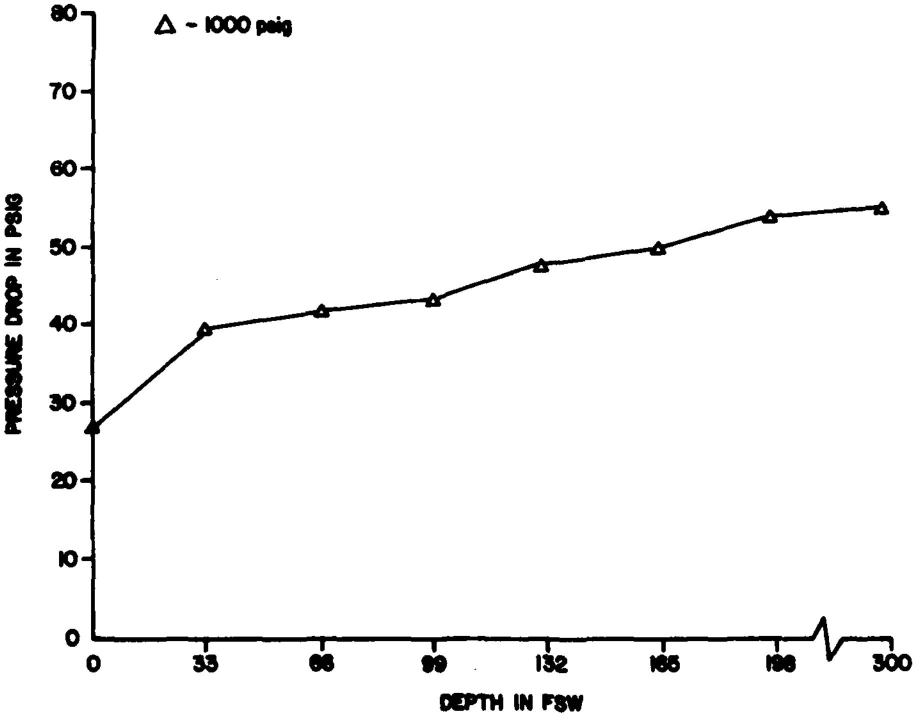

Figure 9B-8. Sportsways W-600 Hydronaut
First stage pressure drop vs. depth at 40 RMV

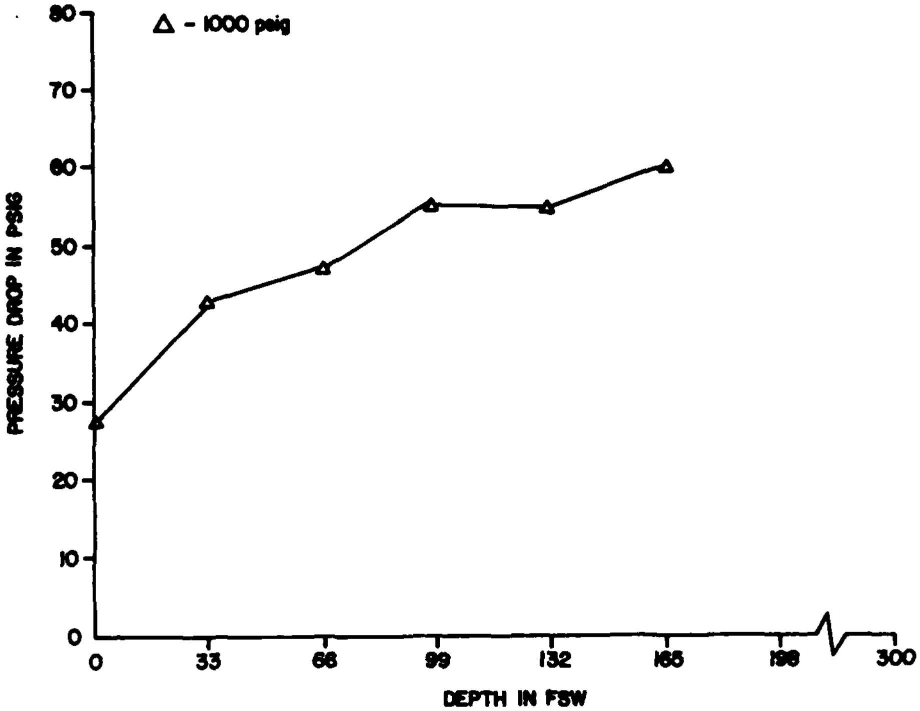

Figure 9B-9. Sportsways W-600 Hydronaut
First stage pressure drop vs. depth at 62.5 RMV

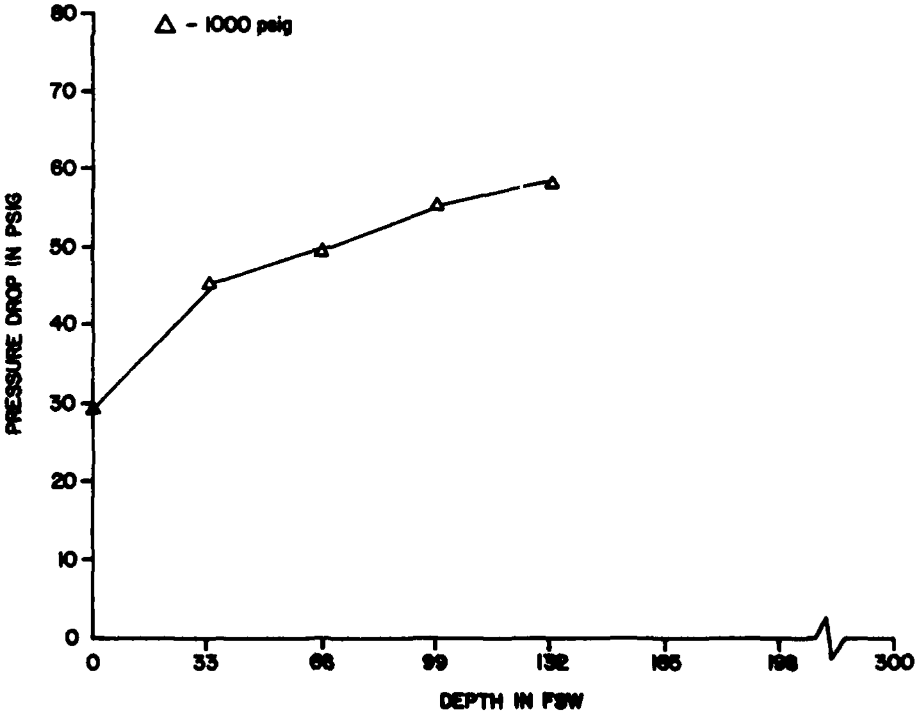

Figure 9B-10. Sportsways W-600 Hydronaut
First stage pressure drop vs. depth at 75 RMV

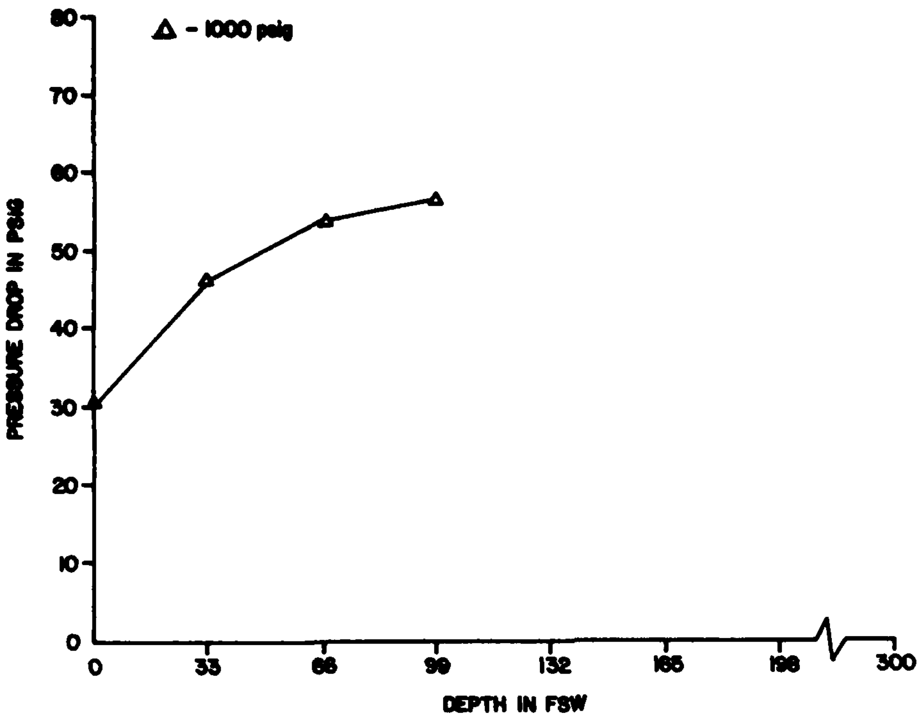

Figure 9B-11. Sportsways W-600 Hydronaut
First stage pressure drop vs. depth at 90 RMV

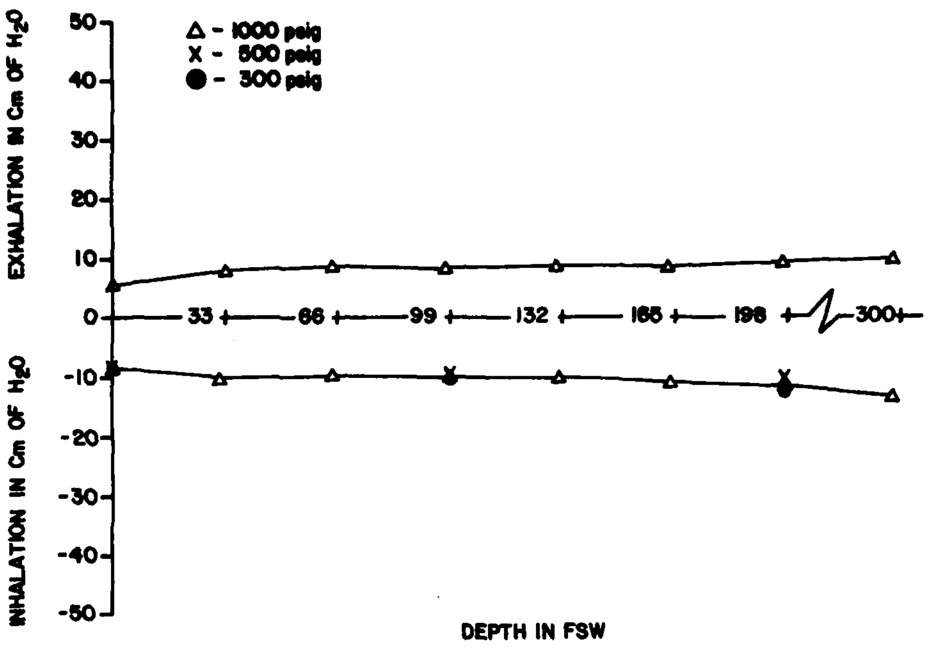

Figure 9C-1. Sportsways W-900 Waterlung
Breathing resistance vs. depth at 22.5 RMV

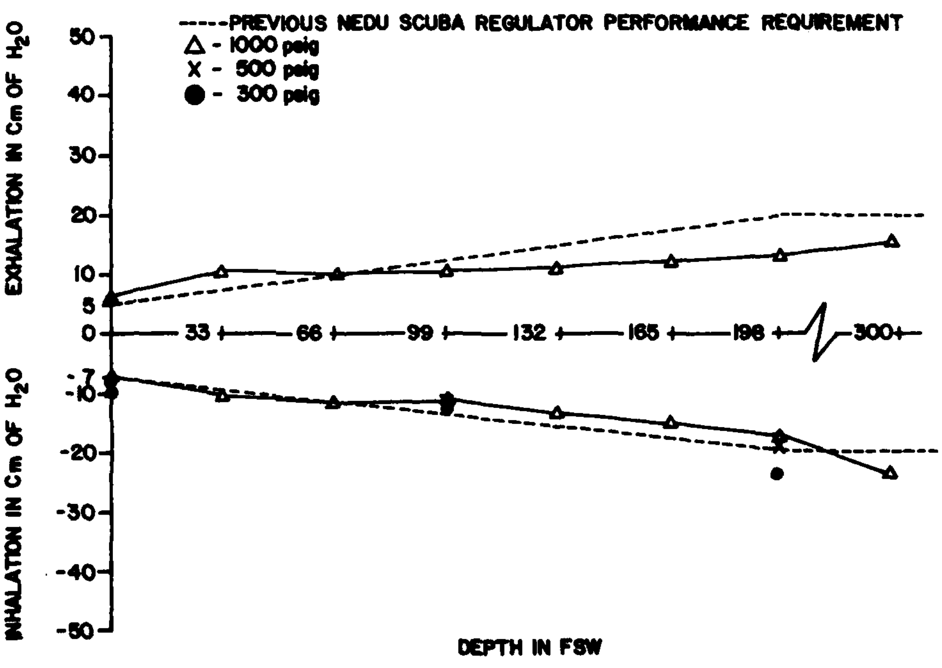

Figure 9C-2. Sportsways W-900 Waterlung
Breathing resistance vs. depth at 40 RMV

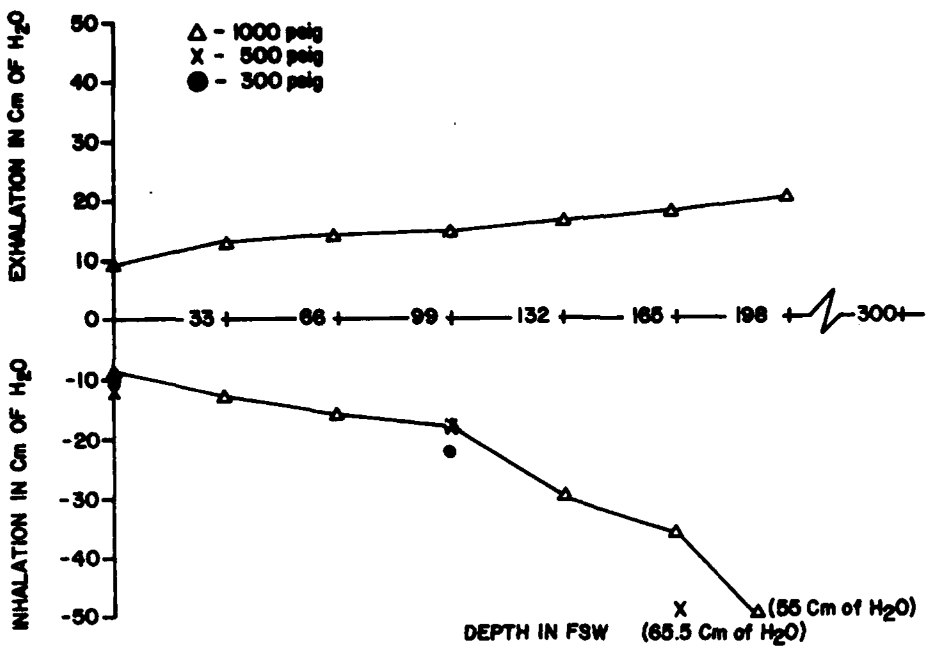

Figure 9C-3. Sportsways W-900 Waterlung
Breathing resistance vs. depth at 62.5 RMV

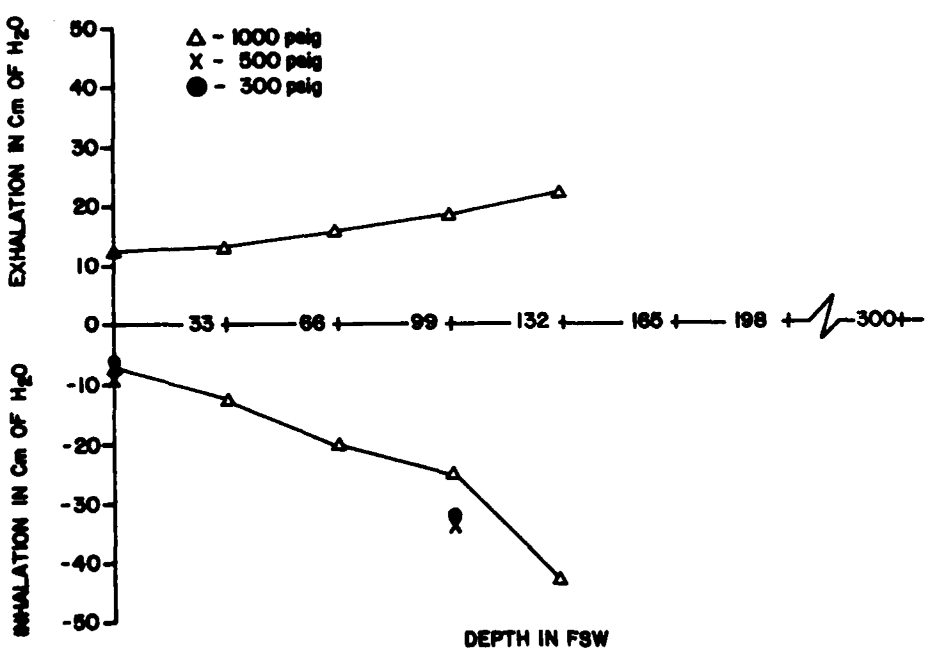

Figure 9C-4. Sportsways W-900 Waterlung
Breathing resistance vs. depth at 75 RMV

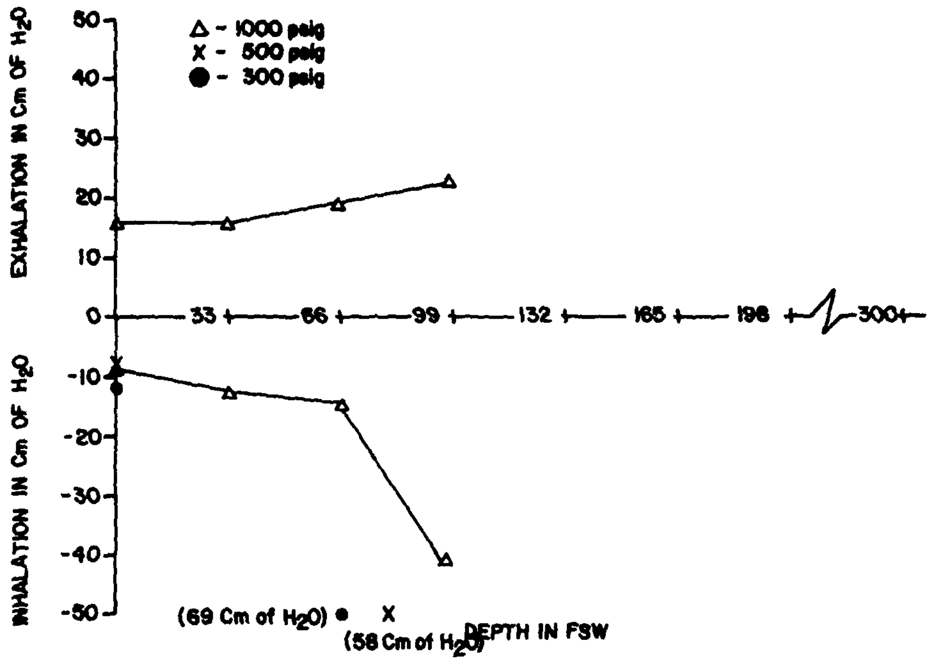

Figure 9C-5. Sportsways W-900 Waterlung
Breathing resistance vs. depth at 90 RMV

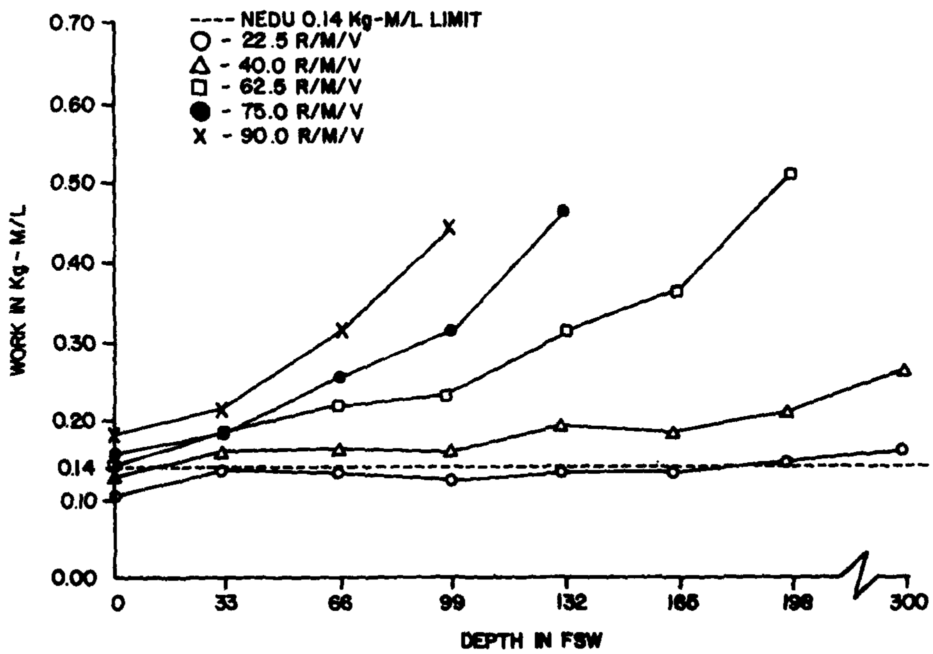

Figure 9C-6. Sportsways W-900 Waterlung
Breathing work vs. depth at 1000 psig supply pressure

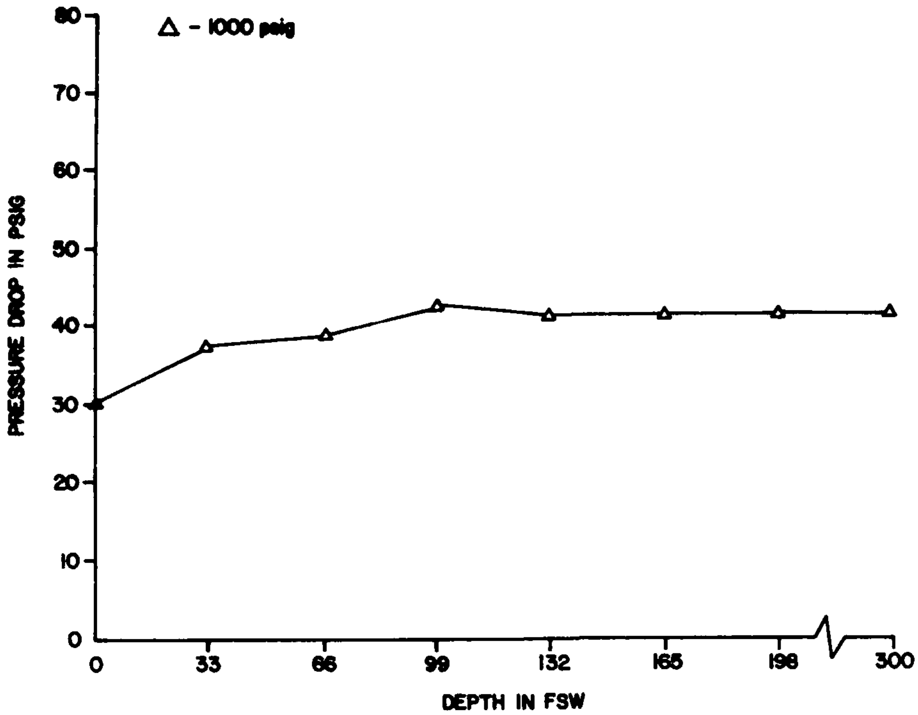

Figure 9C-7. Sportsways W-900 Waterlung
First stage pressure drop vs. depth at 22.5 RMV

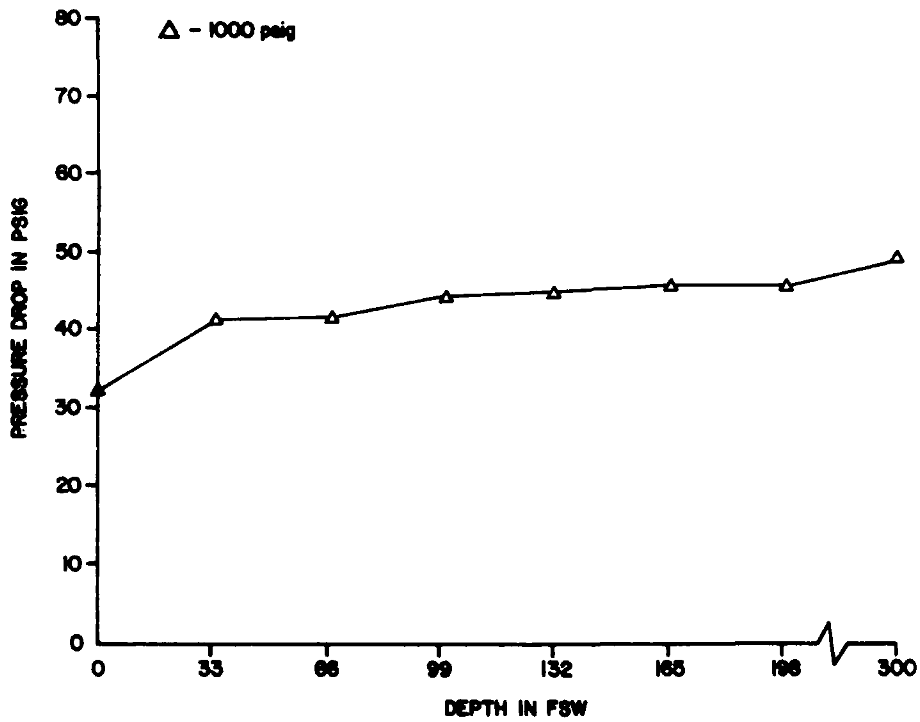

Figure 9C-8. Sportsways W-900 Waterlung
First stage pressure drop vs. depth at 40 RMV

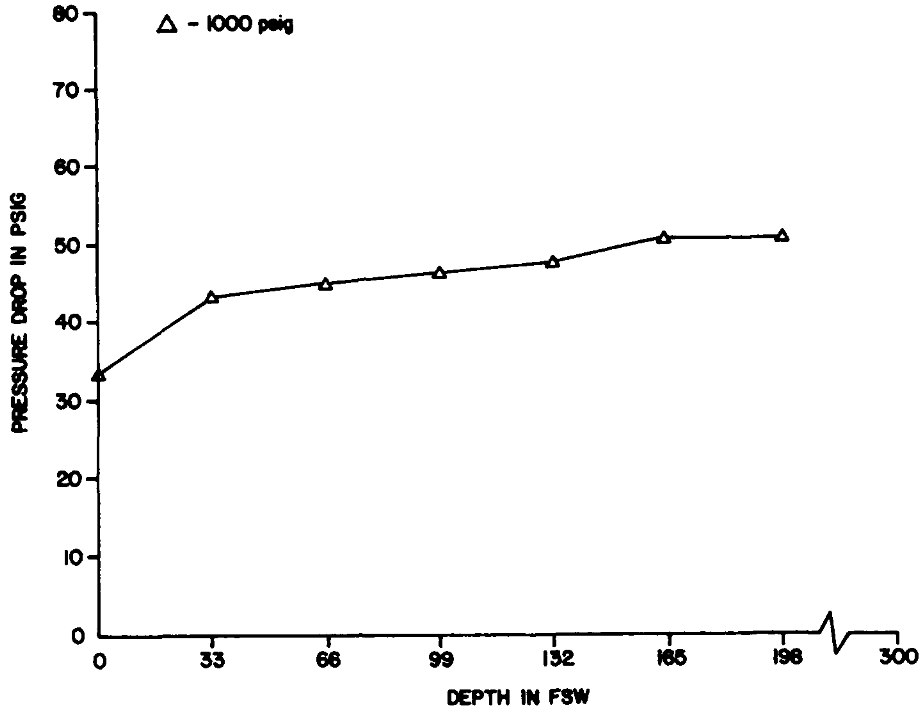

Figure 9C-9. Sportsways W-900 Waterlung
First stage pressure drop vs. depth at 62.5 RMV

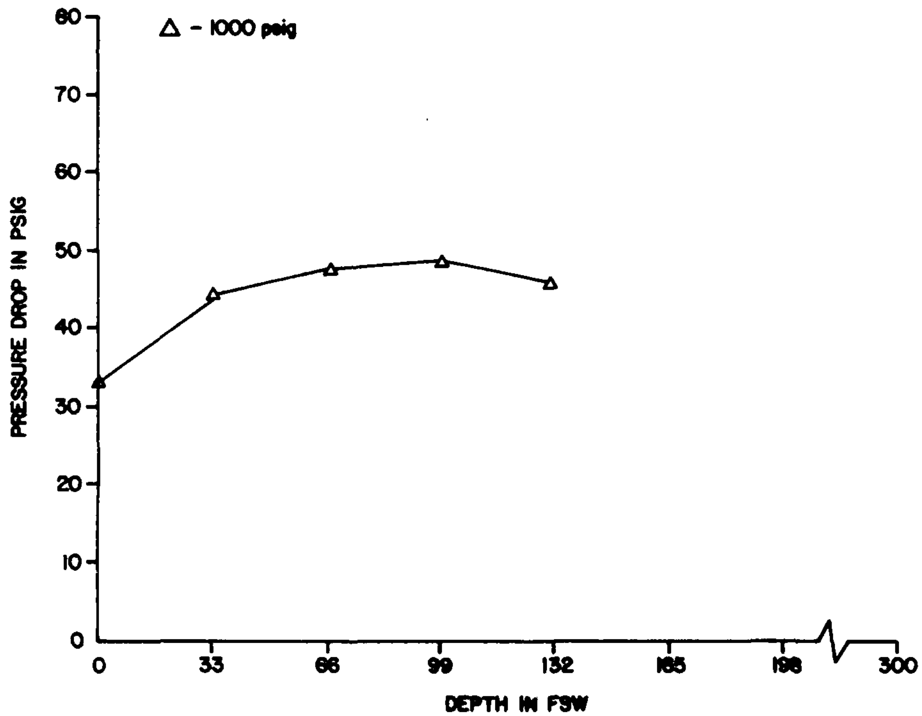

Figure 9C-10. Sportsways W-900 Waterlung
First stage pressure drop vs. depth at 75 RMV

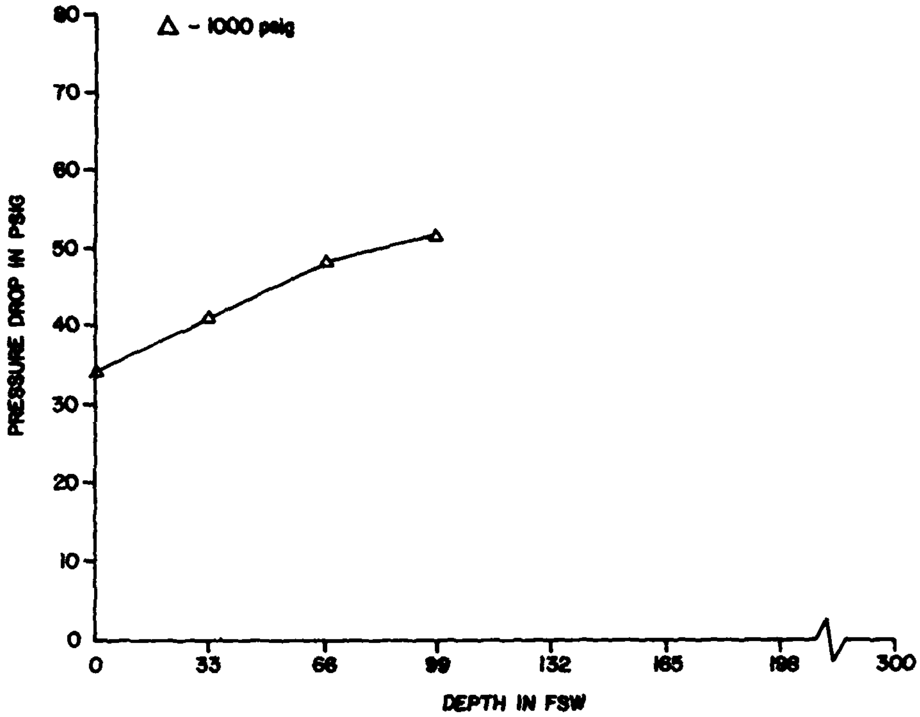

Figure 9C-11. Sportsways W-900 Waterlung
First stage pressure drop vs. depth at 90 RMV

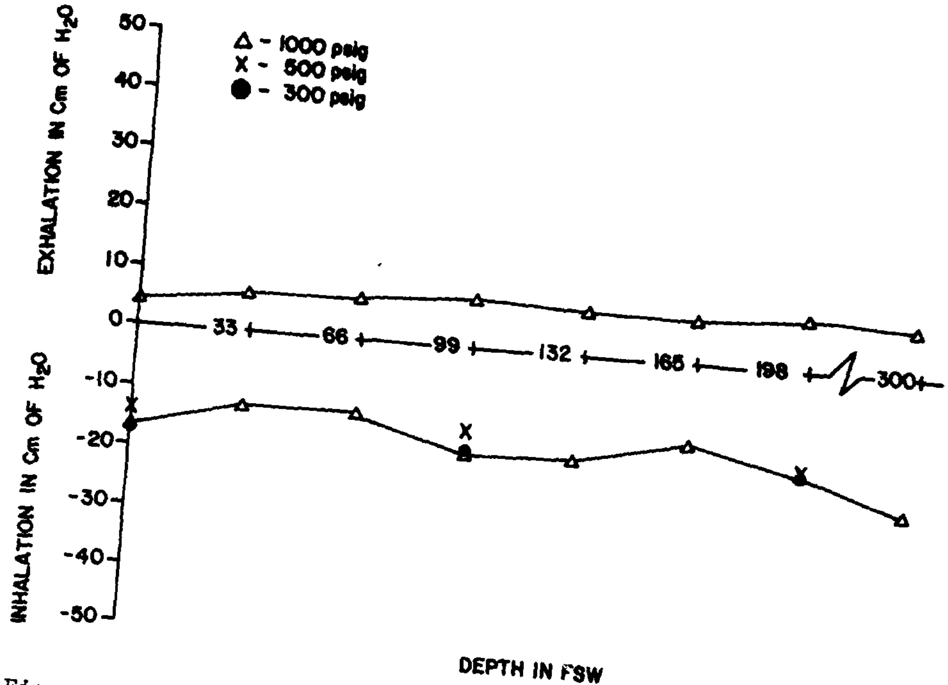

Figure 9D-1. Sportsways W-950 Arctic
Breathing resistance vs. depth at 22.5 RMV

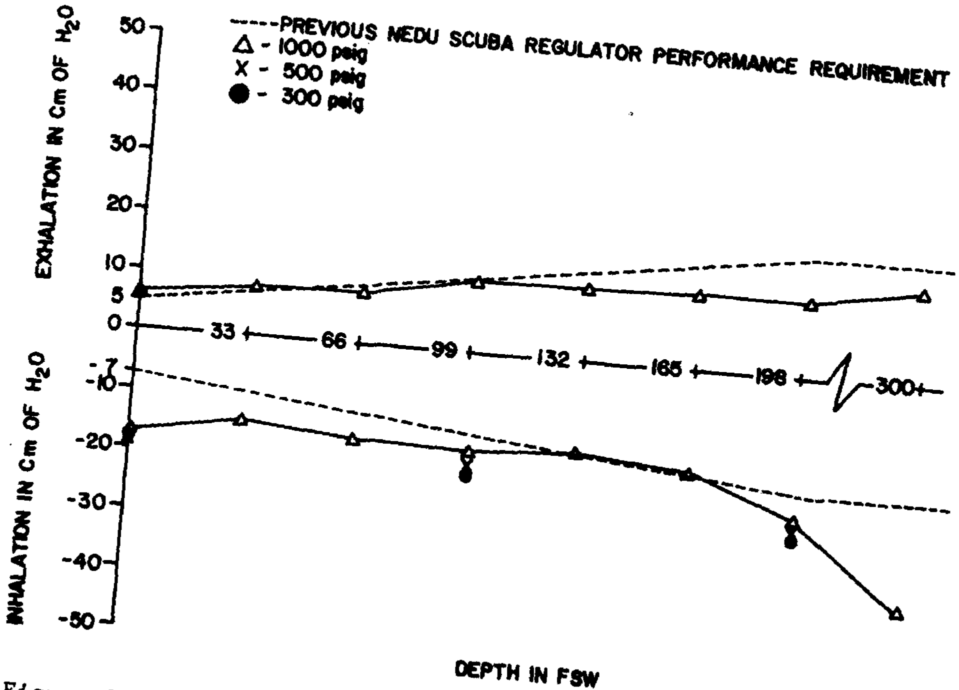

Figure 9D-2. Sportsways W-950 Arctic
Breathing resistance vs. depth at 40 RMV

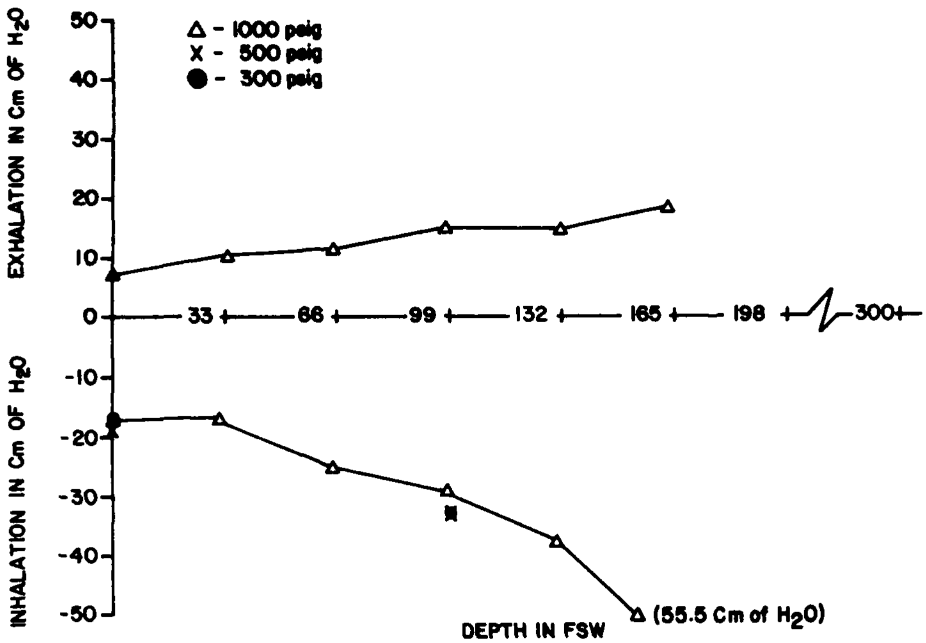

Figure 9D-3. Sportsways W-950 Arctic
Breathing resistance vs. depth at 62.5 RMV

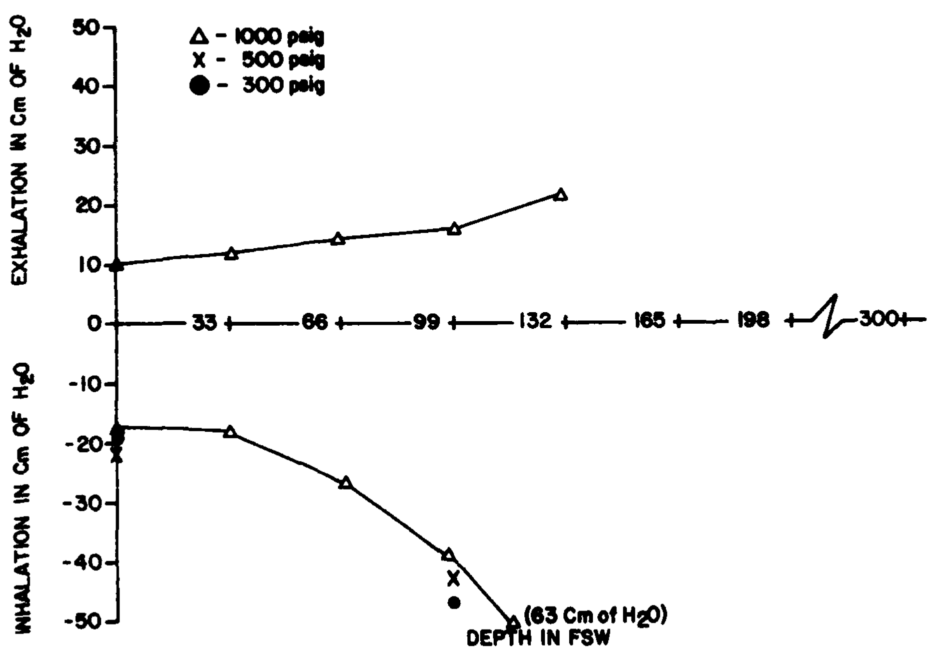

Figure 9D-4. Sportsways W-950 Arctic
Breathing resistance vs. depth at 75 RMV

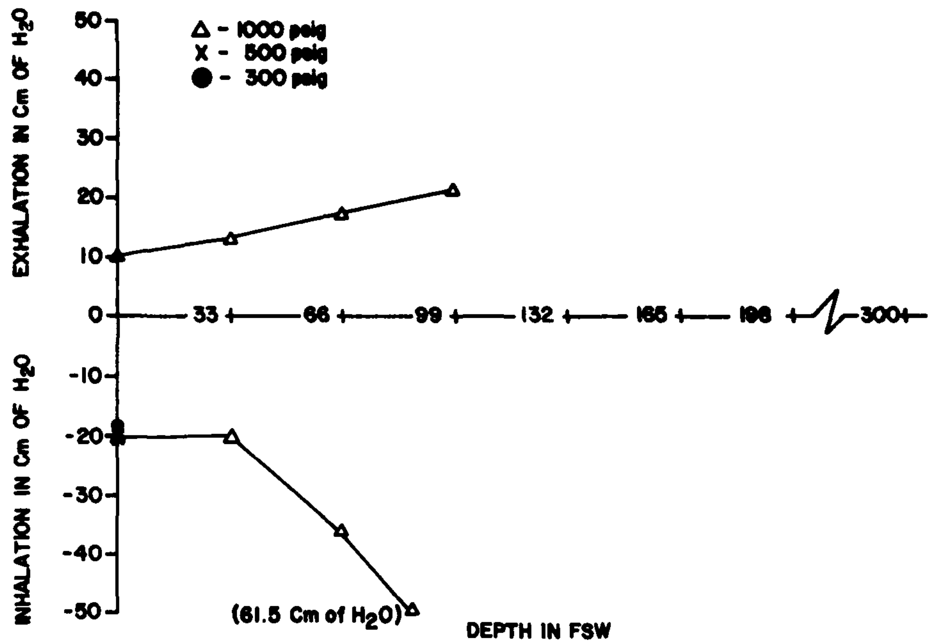

Figure 9D-5. Sportsways W-950 Arctic
Breathing resistance vs. depth at 90 RMV

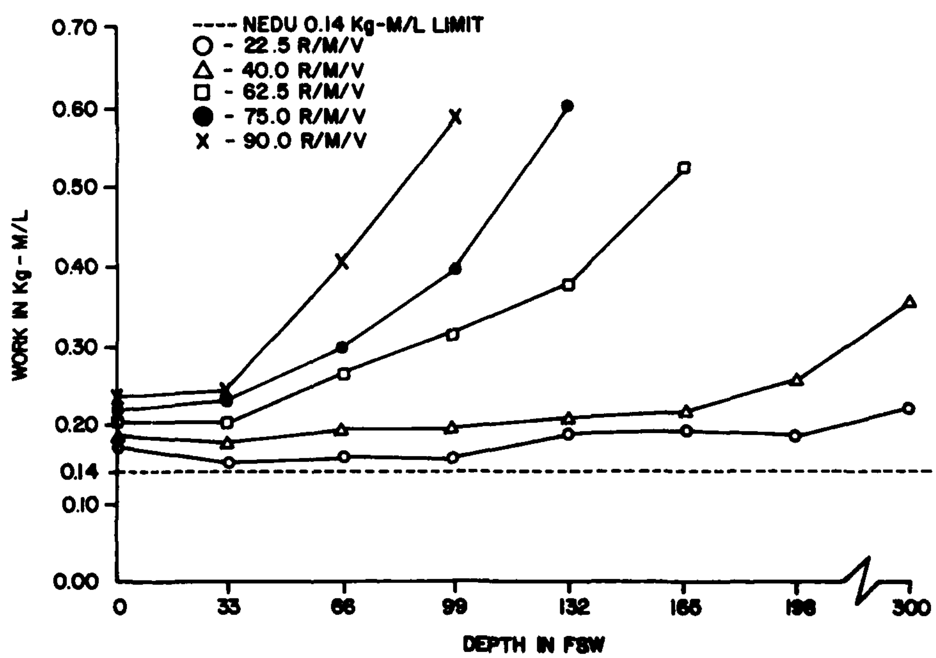

Figure 9D-6. Sportsways W-950 Arctic
Breathing work vs. depth at 1000 psig supply pressure

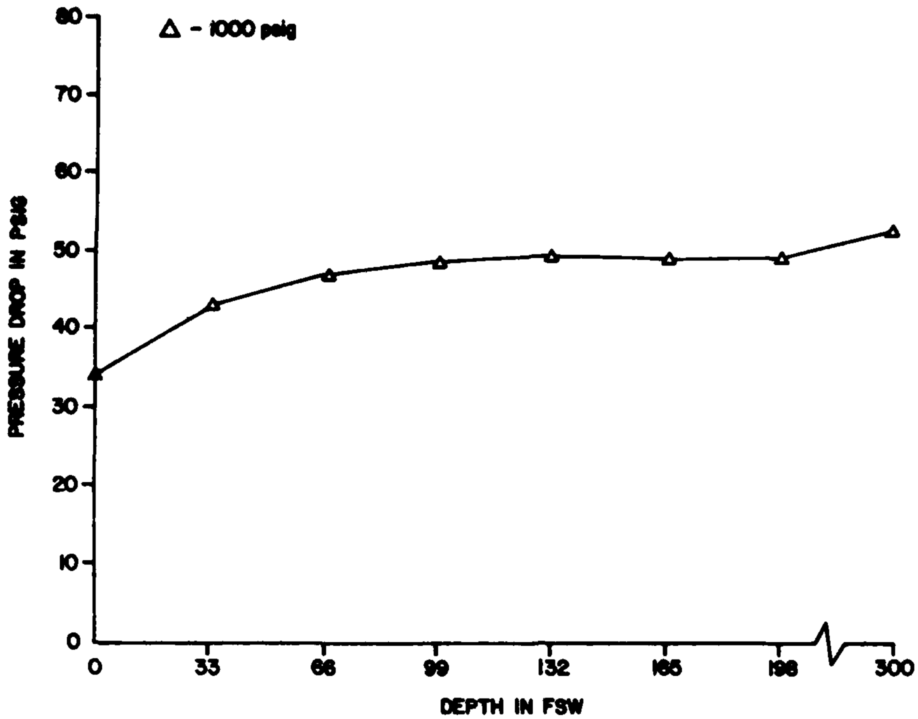

Figure 9D-7. Sportsways W-950 Arctic
First stage pressure drop vs. depth at 22.5 RMV

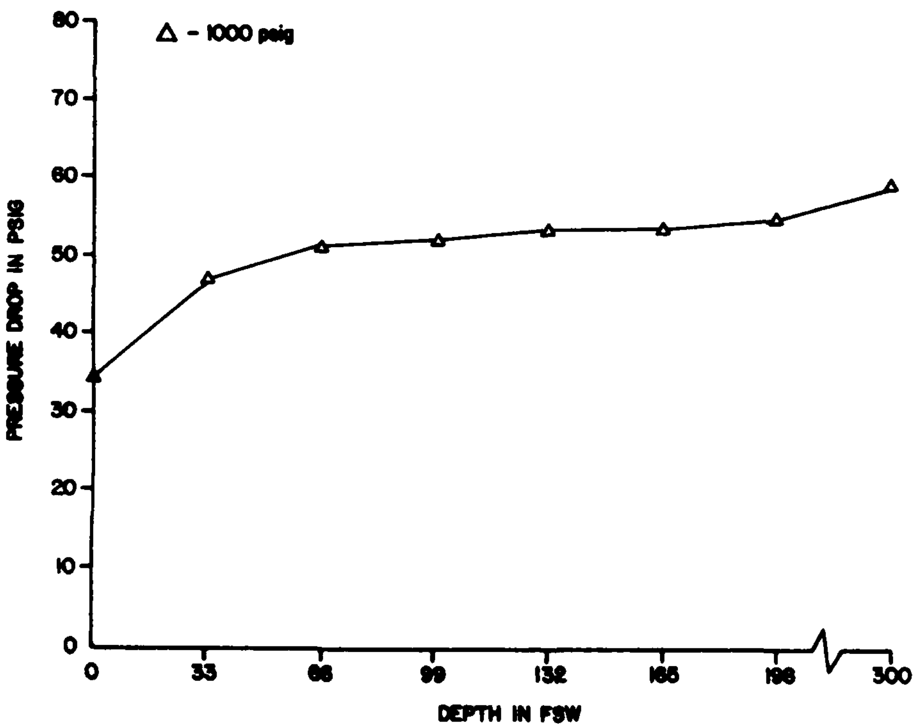

Figure 9D-8. Sportsways W-950 Arctic
First stage pressure drop vs. depth at 40 RMV

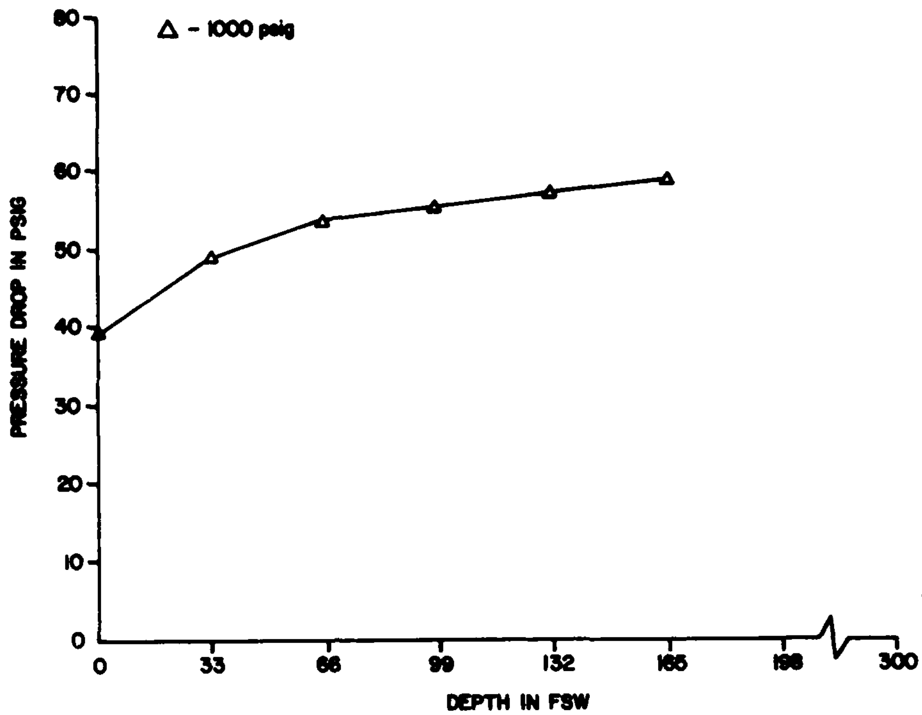

Figure 9D-9. Sportsways W-950 Arctic
First stage pressure drop vs. depth at 62.5 RMV

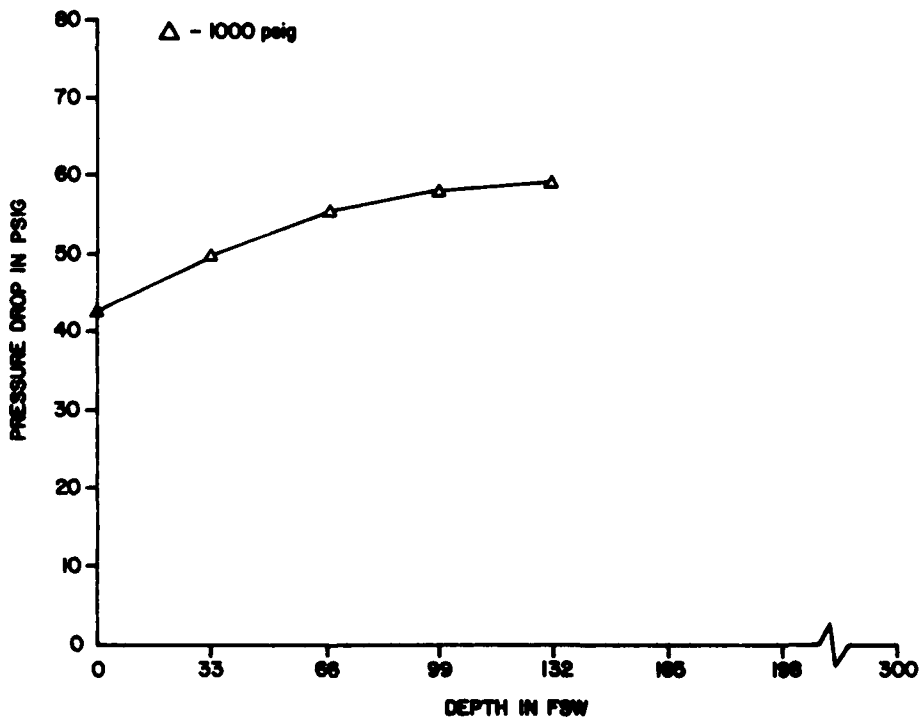

Figure 9D-10. Sportsways W-950 Arctic
First stage pressure drop vs. depth at 75 RMV

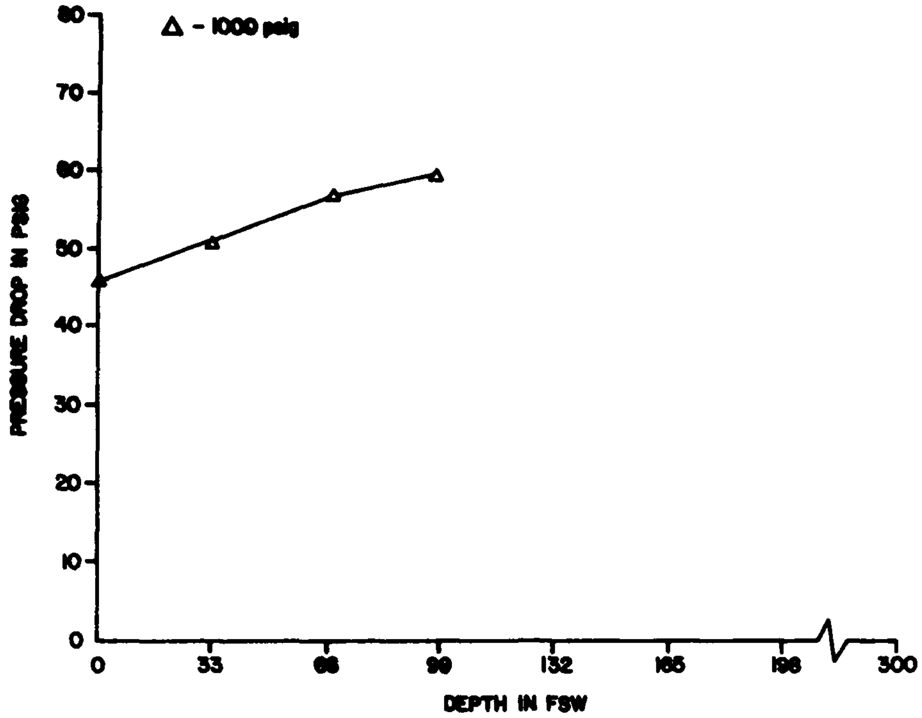

Figure 9D-11. Sportsways W-950 Arctic
First stage pressure drop vs. depth at 90 RMV

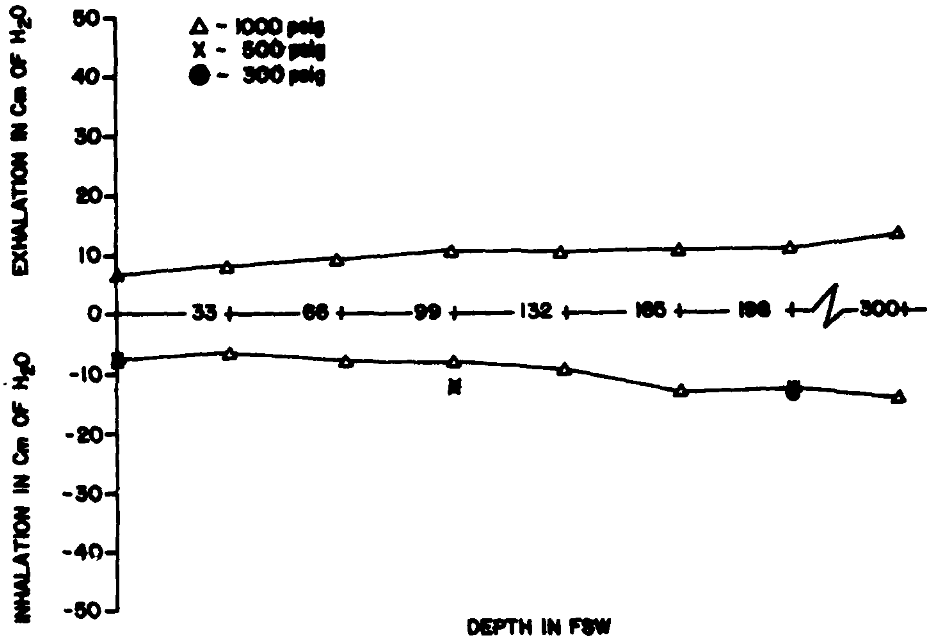

Figure 9E-1. Sportsways Model 1390
Breathing resistance vs. depth at 22.5 RMV

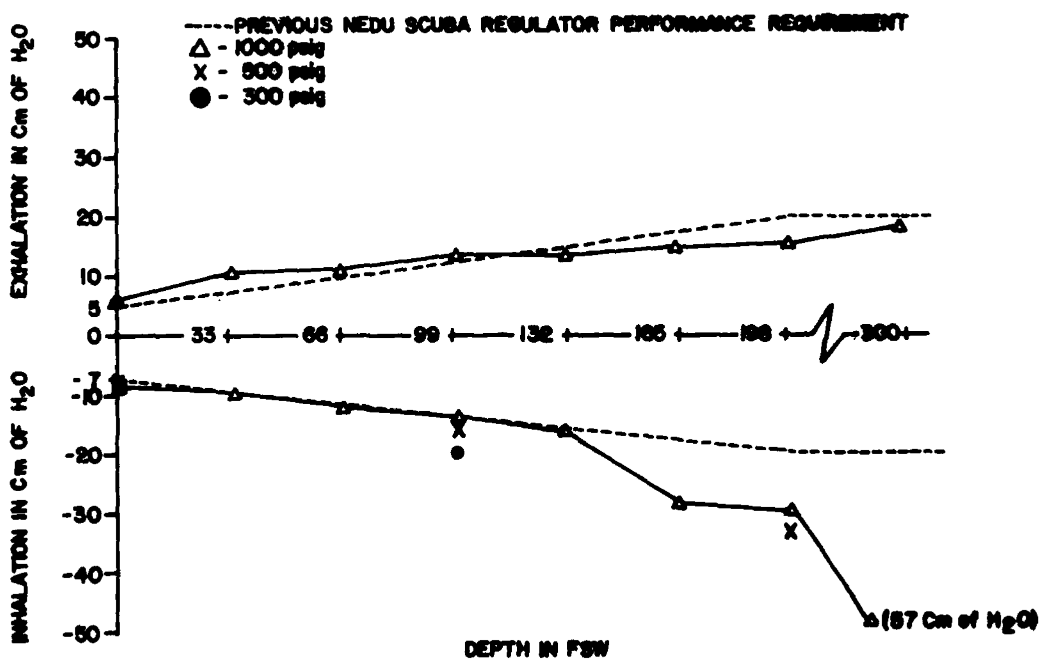

Figure 9E-2. Sportsways Model 1390
Breathing resistance vs. depth at 40 RMV

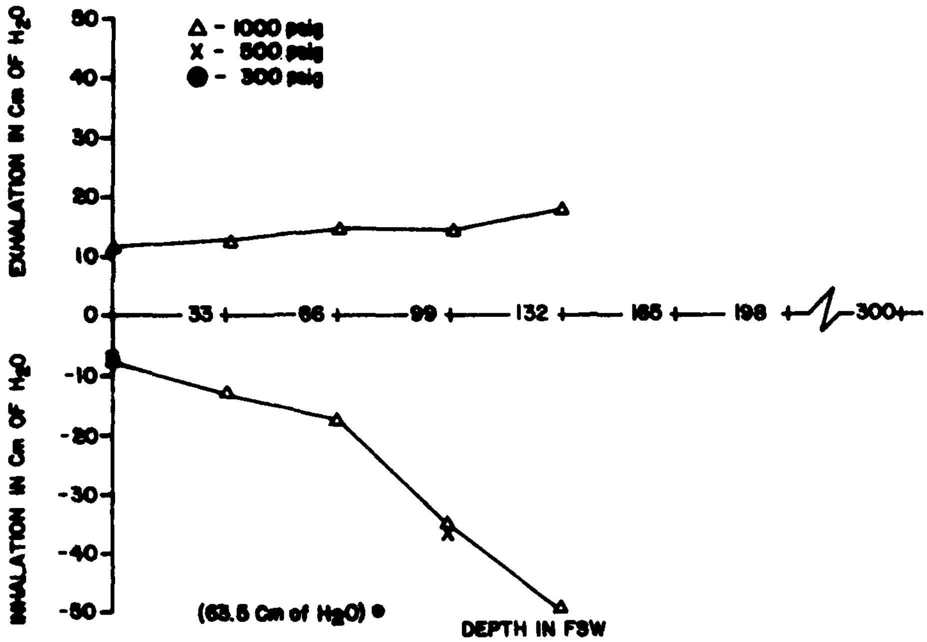

Figure 9E-3. Sportsways Model 1390
Breathing resistance vs. depth at 62.5 RMV

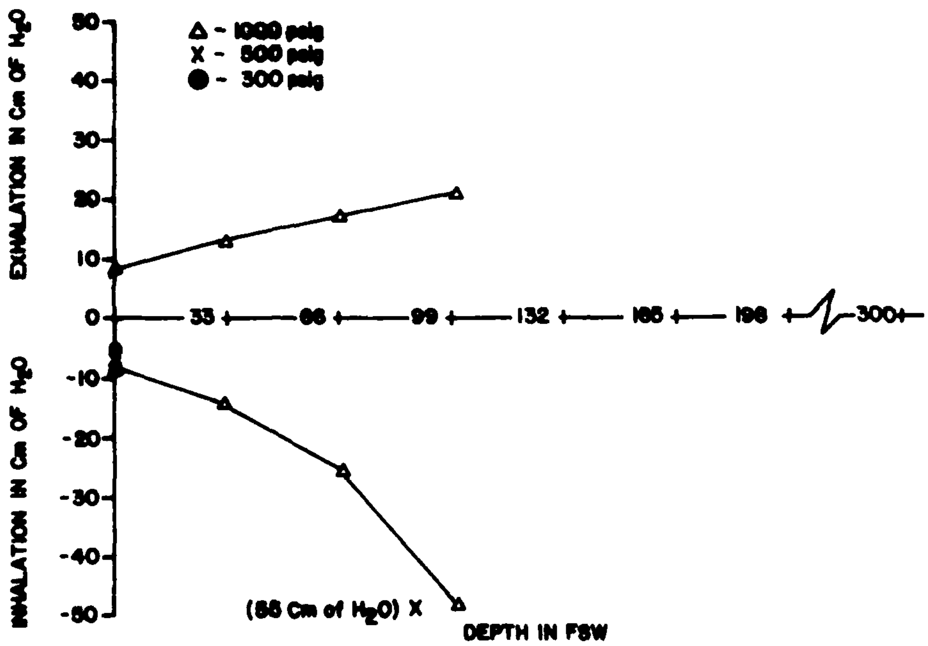

Figure 9E-4. Sportsways Model 1390
Breathing resistance vs. depth at 75 RMV

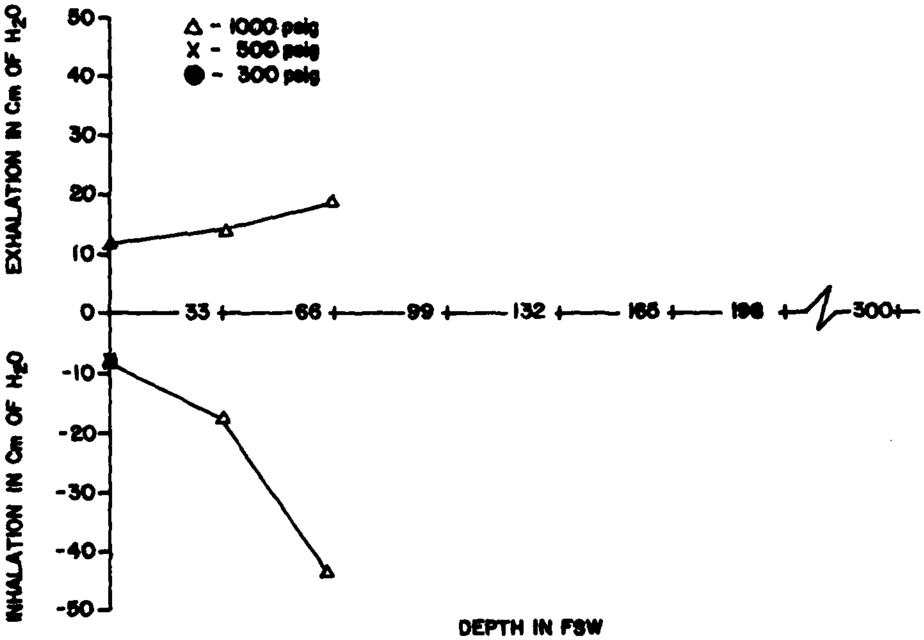

Figure 9E-5. Sportsways Model 1390
Breathing resistance vs. depth at 90 RMV

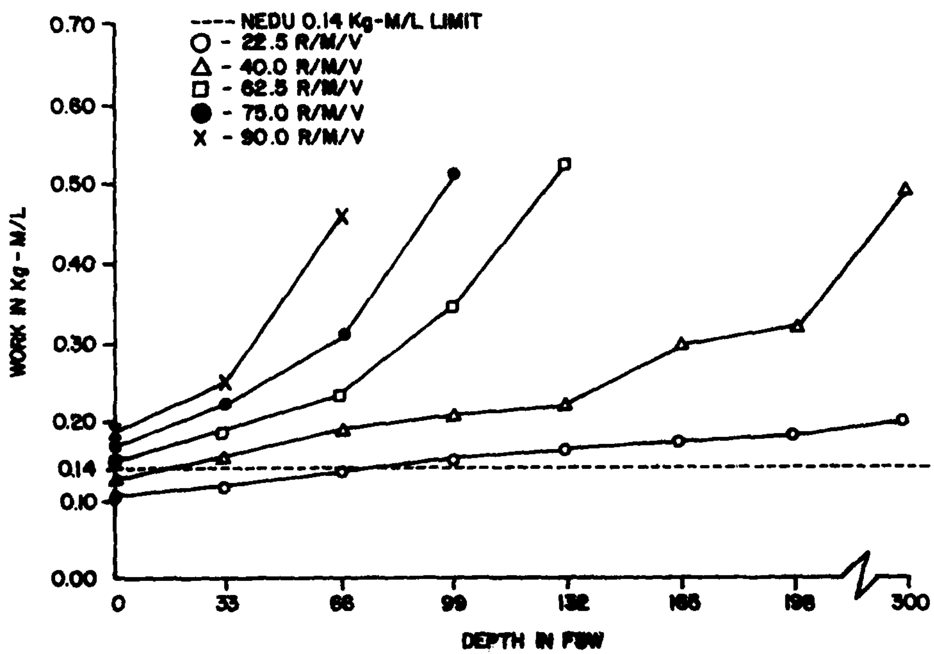

Figure 9E-6. Sportsways Model 1390
Breathing work vs. depth at 1000 psig supply pressure

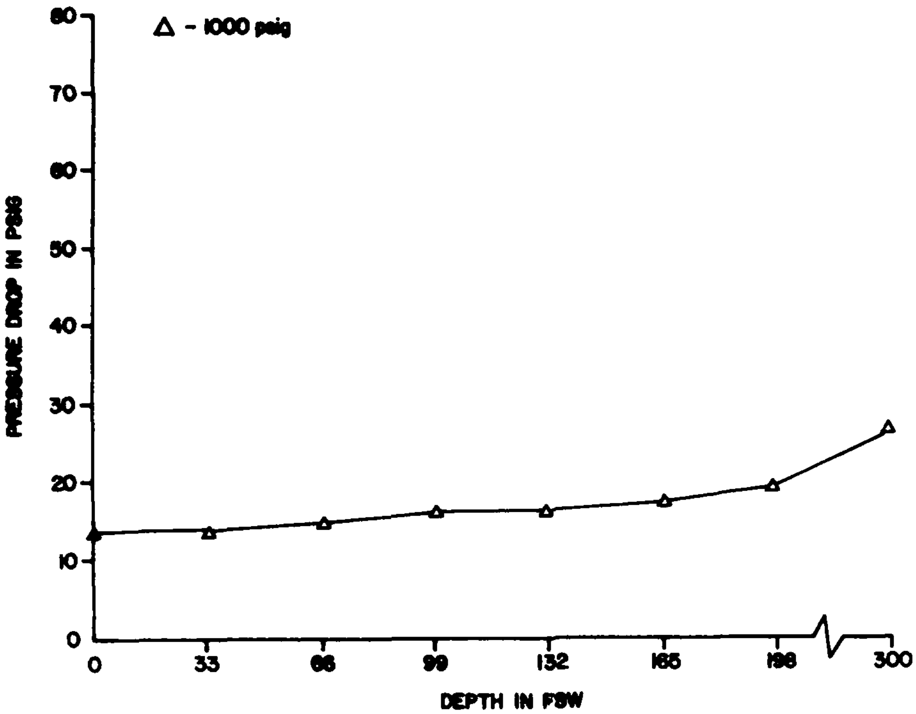

Figure 9E-7. Sportsways Model 1390
First stage pressure drop vs. depth at 22.5 RMV

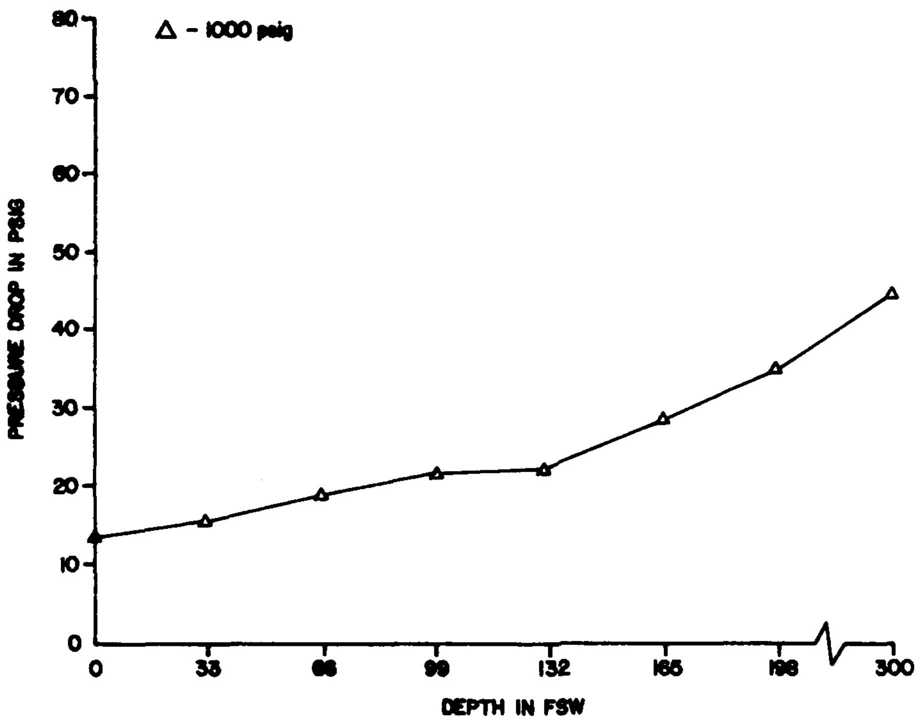

Figure 9E-8. Sportsways Model 1390
First stage pressure drop vs. depth at 40 RMV

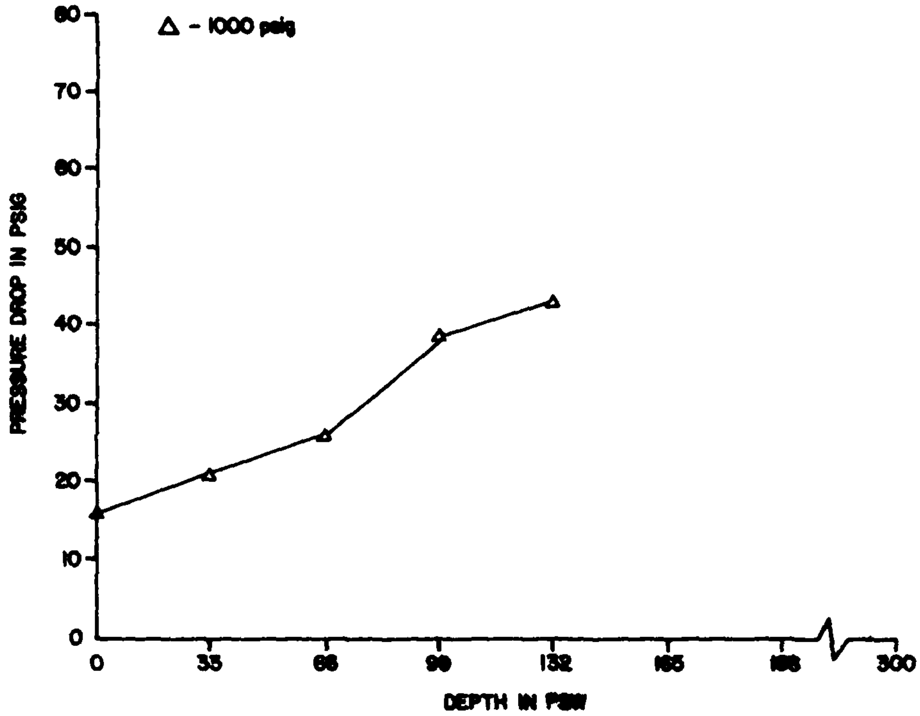

Figure 9E-9. Sportsways Model 1390
First stage pressure drop vs. depth at 62.5 RMV

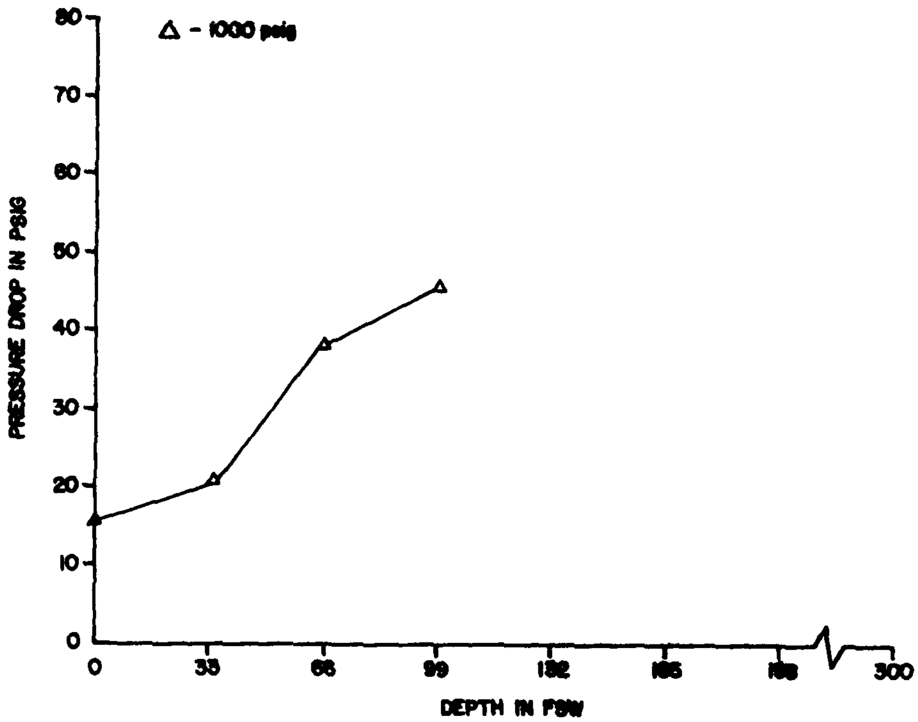

Figure 9E-10. Sportsways Model 1390
First stage pressure drop vs. depth at 75 RMV

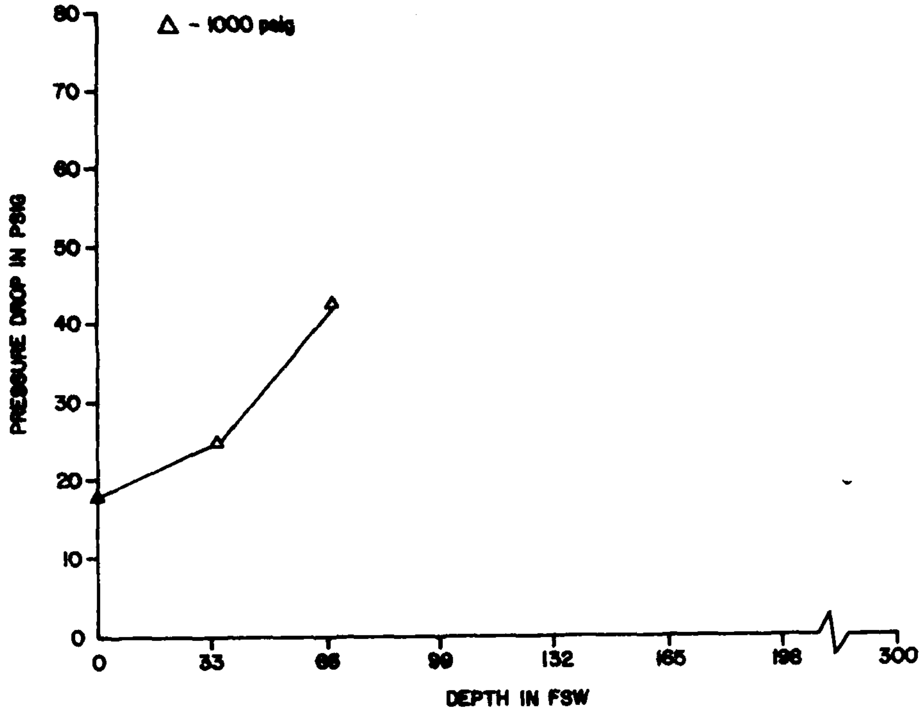

Figure 9E-11. Sportsways Model 1390
First stage pressure drop vs. depth at 90 RMV

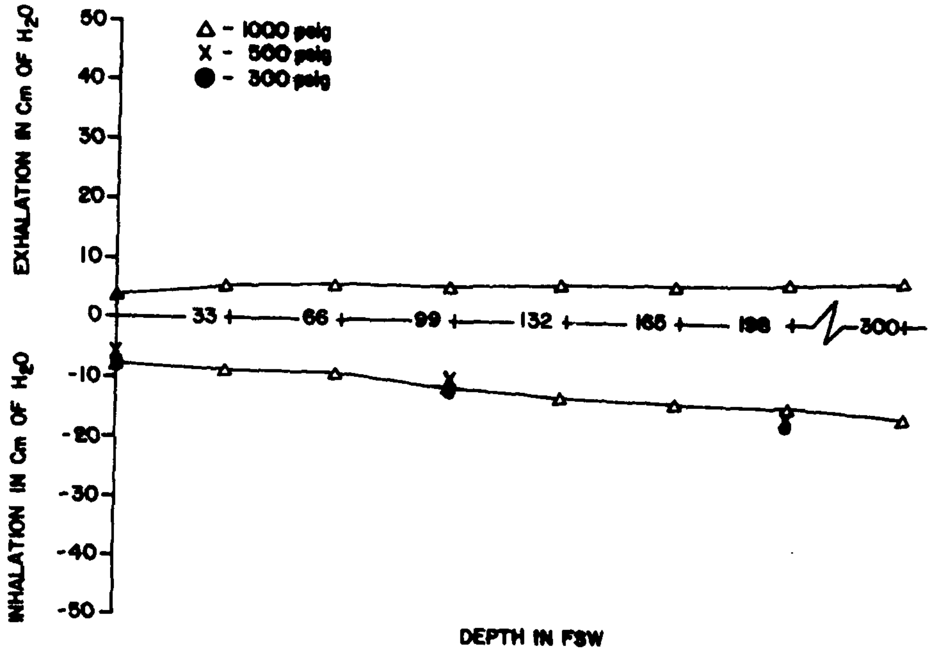

Figure 10A-1. Sub Aquatic Systems Sub II
Breathing resistance vs. depth at 22.5 RMV

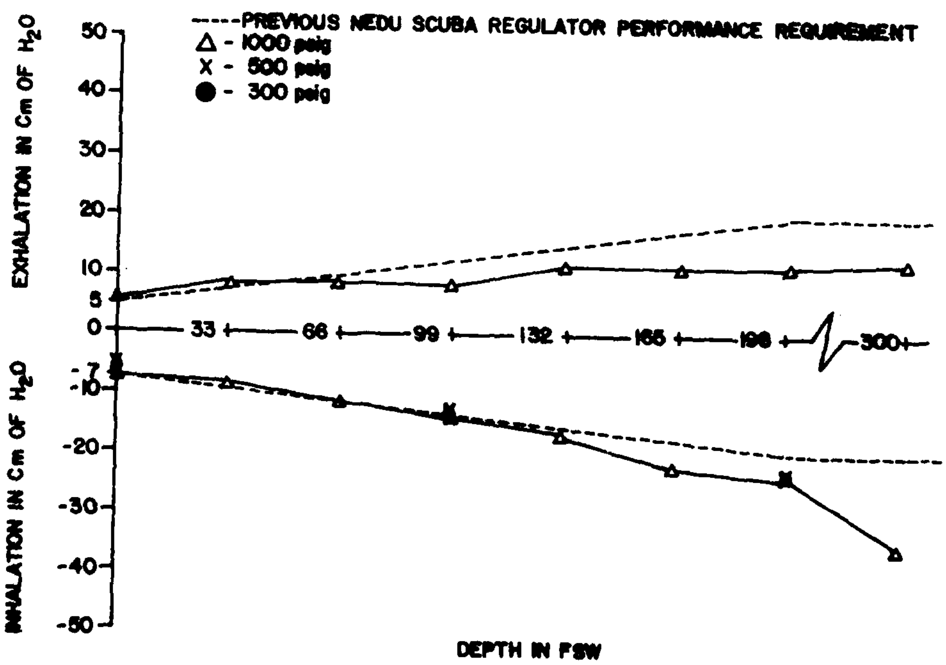

Figure 10A-2. Sub Aquatic Systems Sub II
Breathing resistance vs. depth at 40 RMV

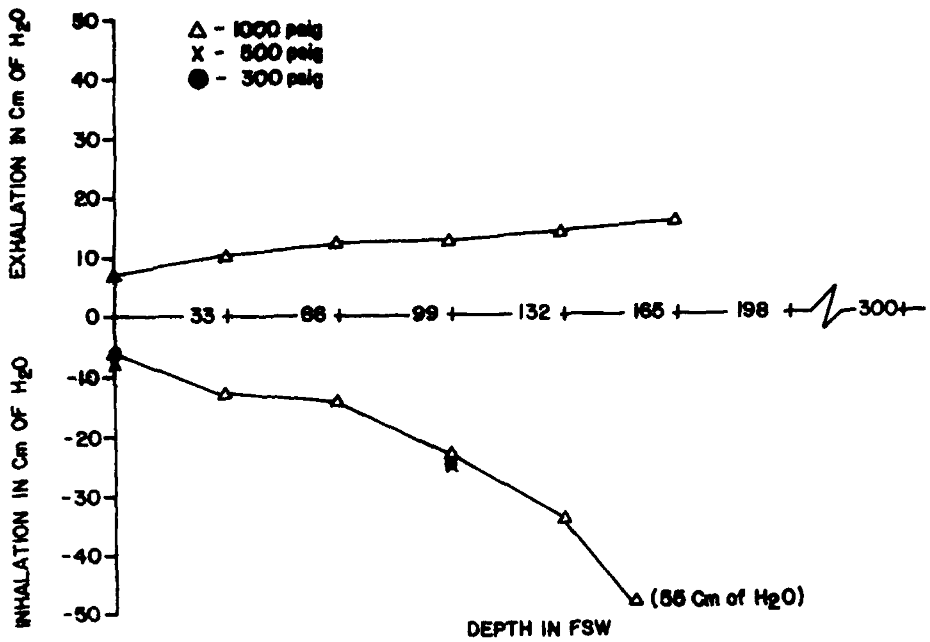

Figure 10A-3. Sub Aquatic Systems Sub II
Breathing resistance vs. depth at 62.5 RMV

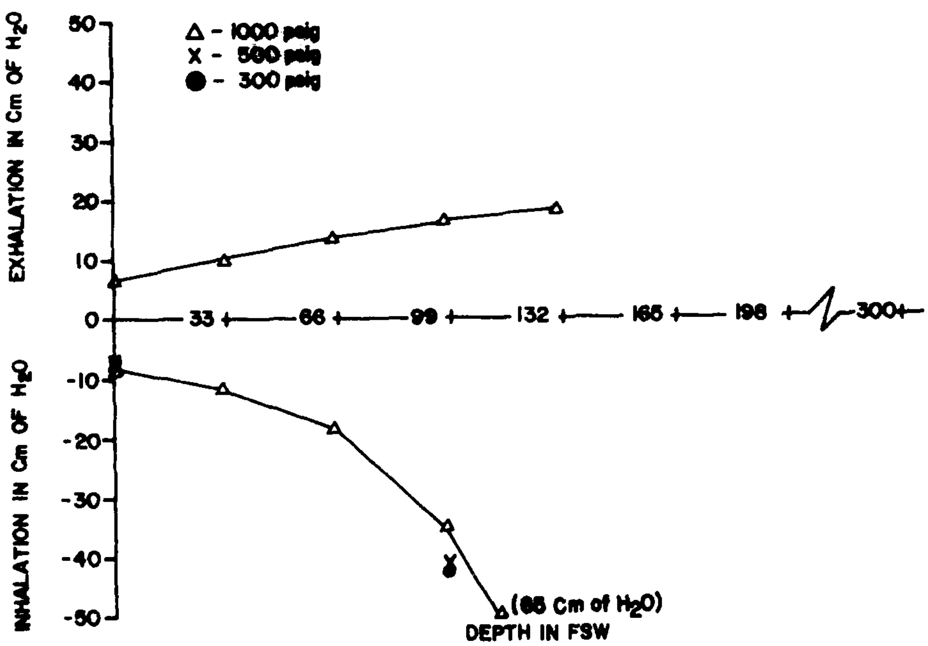

Figure 10A-4. Sub Aquatic Systems Sub II
Breathing resistance vs. depth at 75 RMV

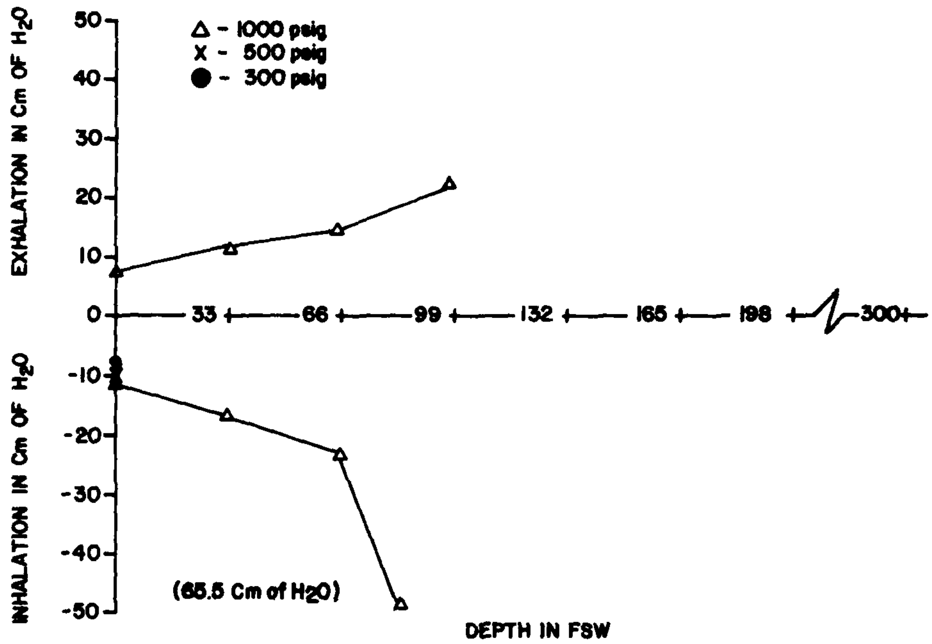

Figure 10A-5. Sub Aquatic Systems Sub II
Breathing resistance vs. depth at 90 RMV

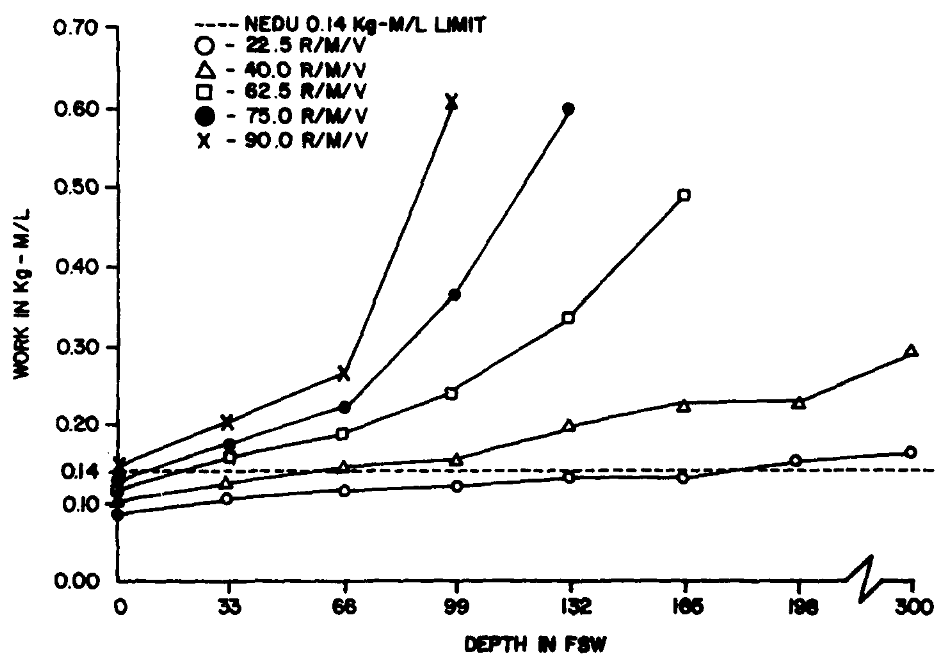

Figure 10A-6. Sub Aquatic Systems Sub II
Breathing work vs. depth at 1000 psig supply pressure

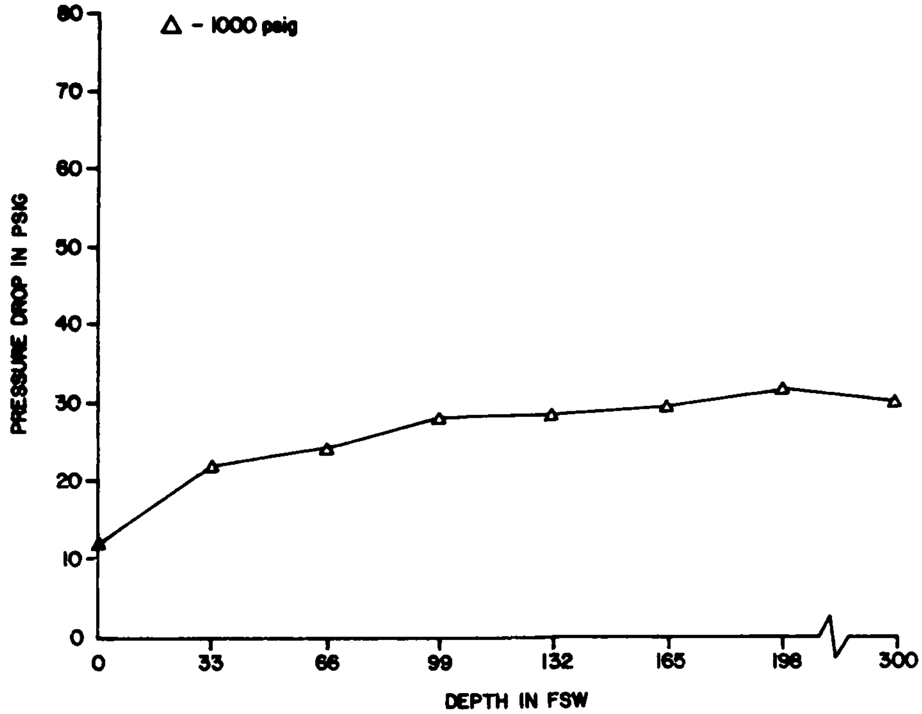

Figure 10A-7. Sub Aquatic Systems Sub II
First stage pressure drop vs. depth at 22.5 RMV

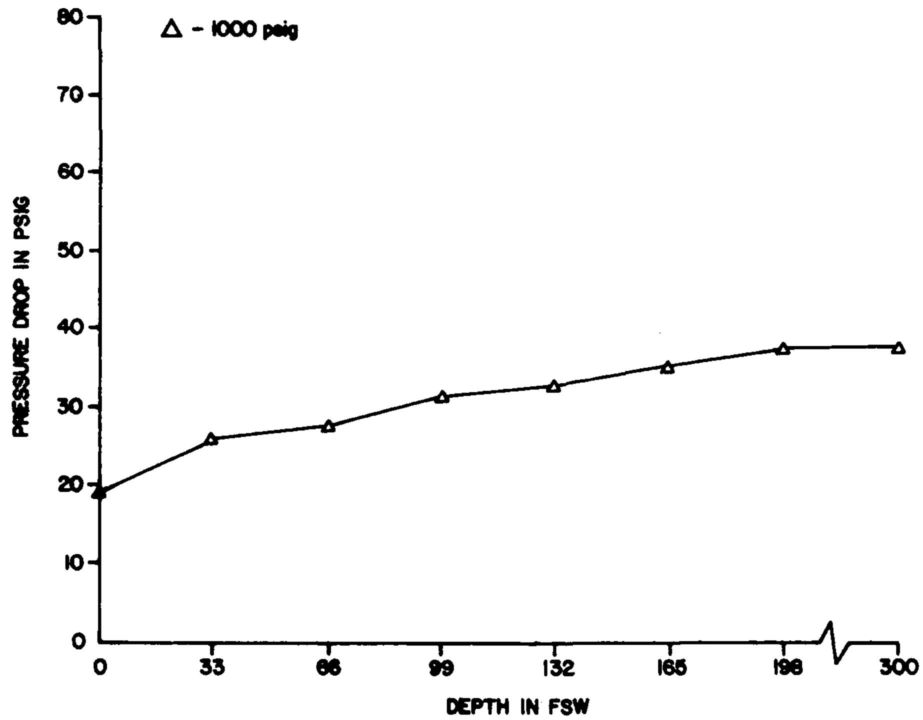

Figure 10A-8. Sub Aquatic Systems Sub II
First stage pressure drop vs. depth at 40 RMV

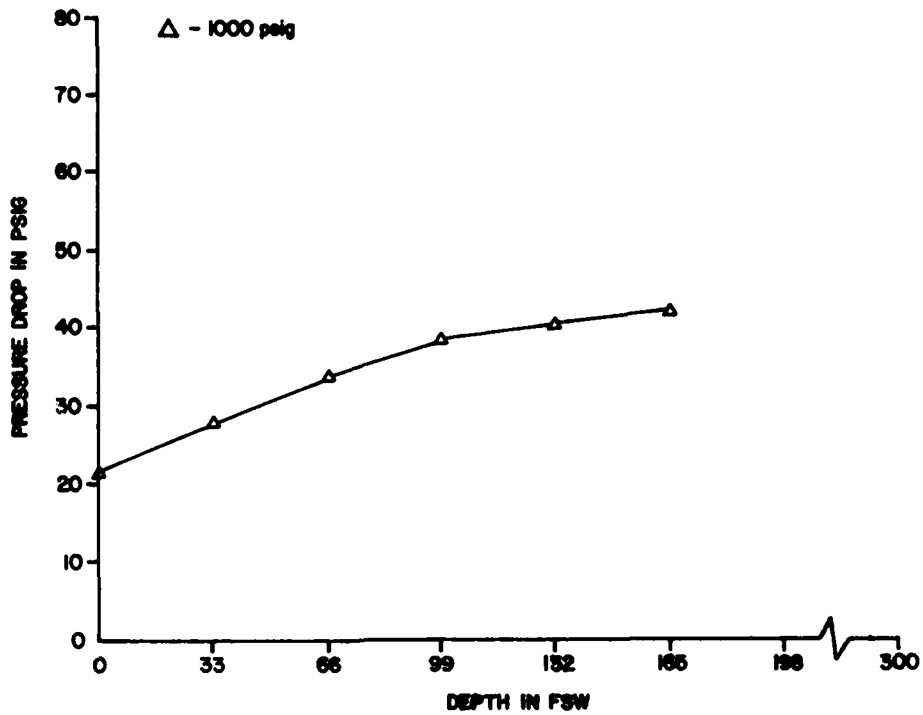

Figure 10A-9. Sub Aquatic Systems Sub II
First stage pressure drop vs. depth at 62.5 RMV

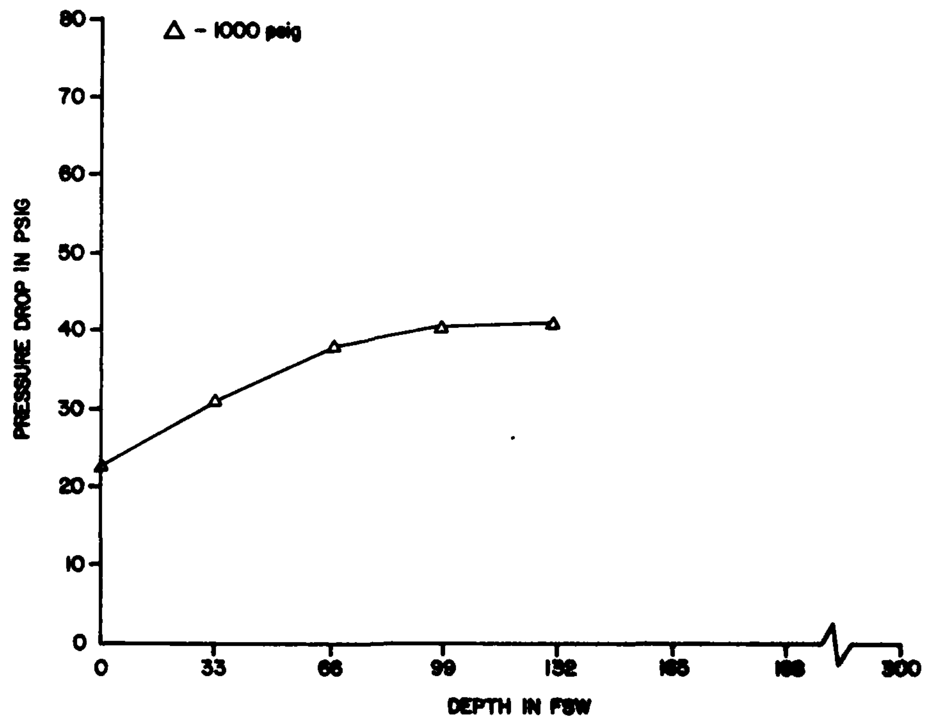

Figure 10A-10. Sub Aquatic Systems Sub II
First stage pressure drop vs. depth at 75 RMV

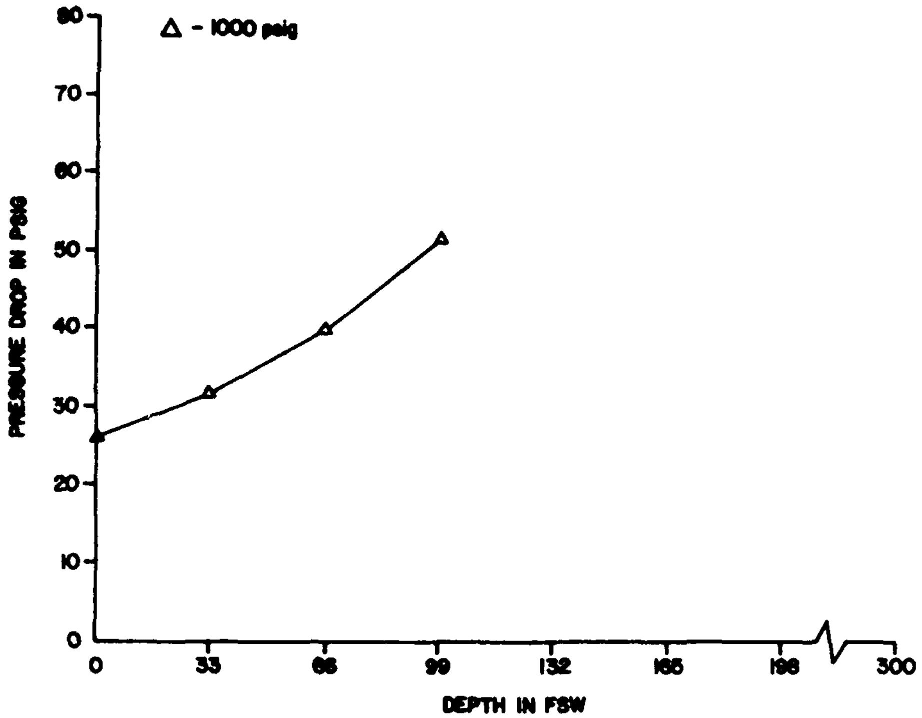

Figure 10A-11. Sub Aquatic Systems Sub II
First stage pressure drop vs. depth at 90 RMV

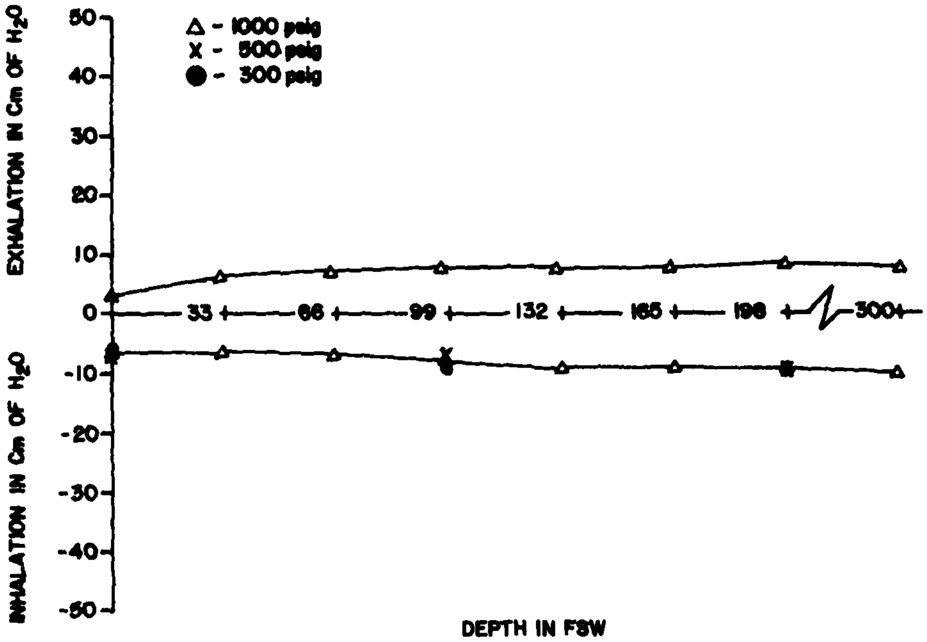

Figure 10B-1. Sub Aquatic Systems Sub X
Breathing resistance vs. depth at 22.5 RMV

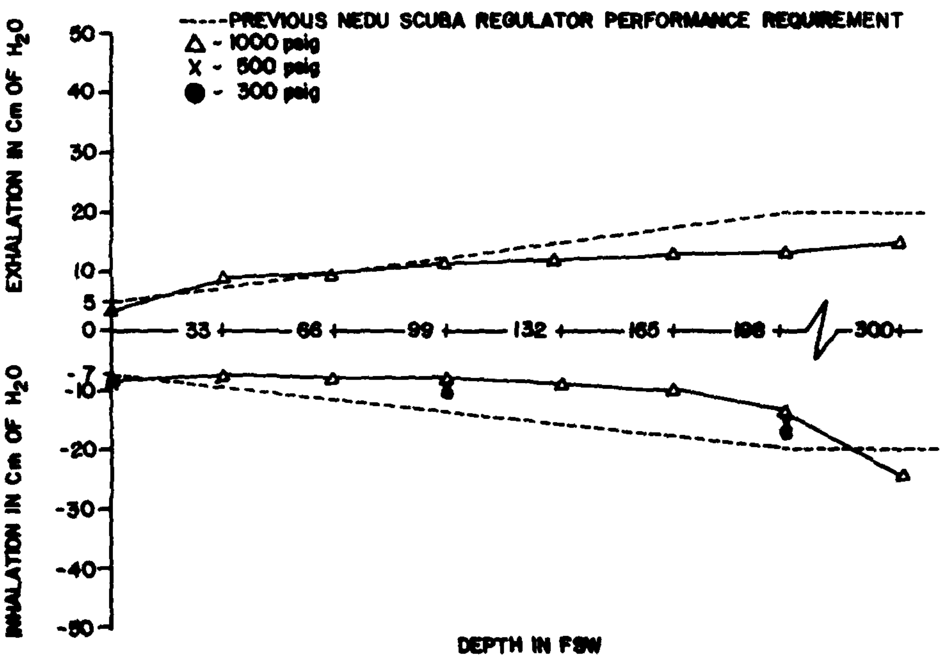

Figure 10B-2. Sub Aquatic Systems Sub X
Breathing resistance vs. depth at 40 RMV

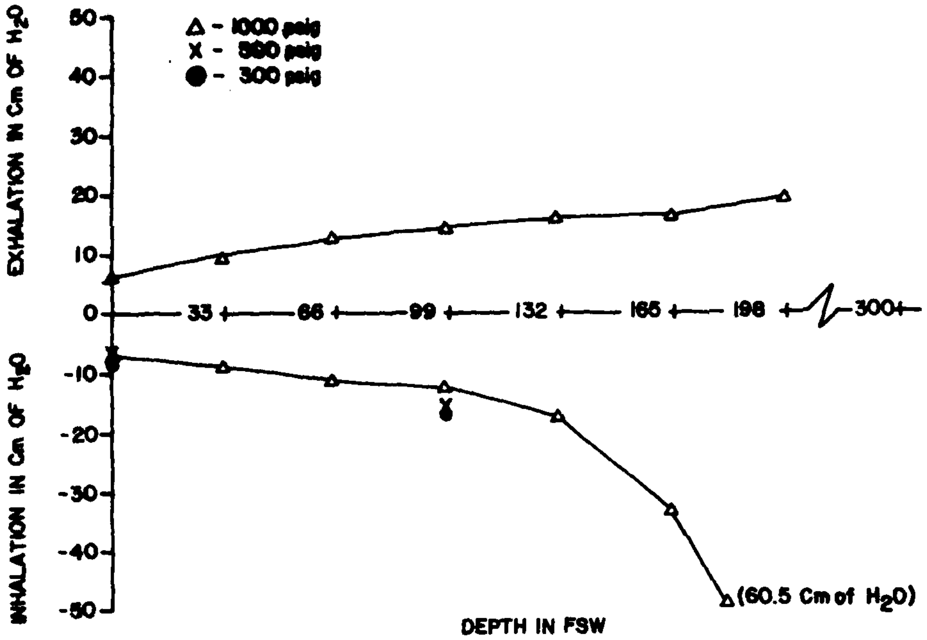

Figure 10B-3. Sub Aquatic Systems Sub X
Breathing resistance vs. depth at 62.5 RMV

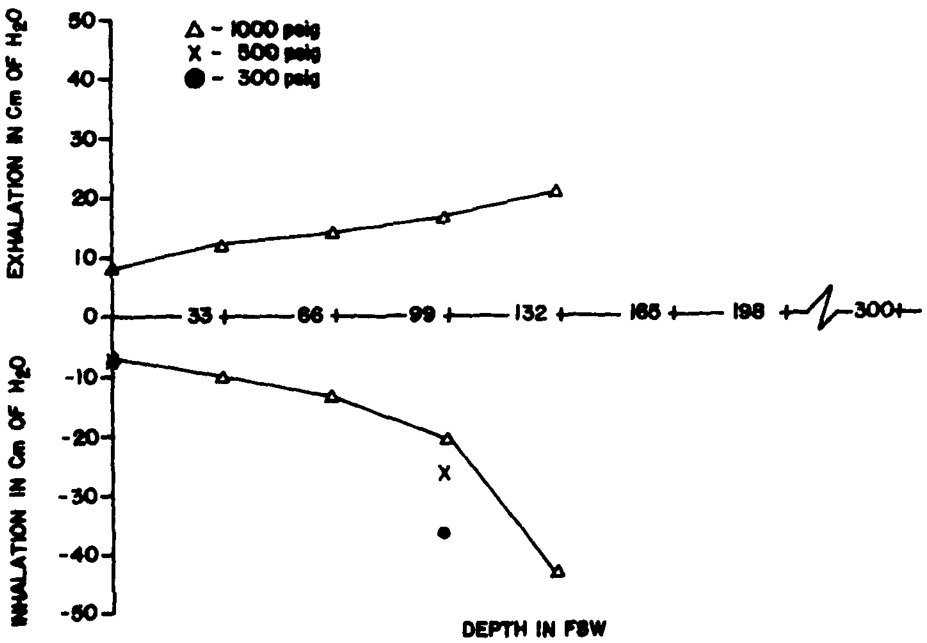

Figure 10B-4. Sub Aquatic Systems Sub X
Breathing resistance vs. depth at 75 RMV

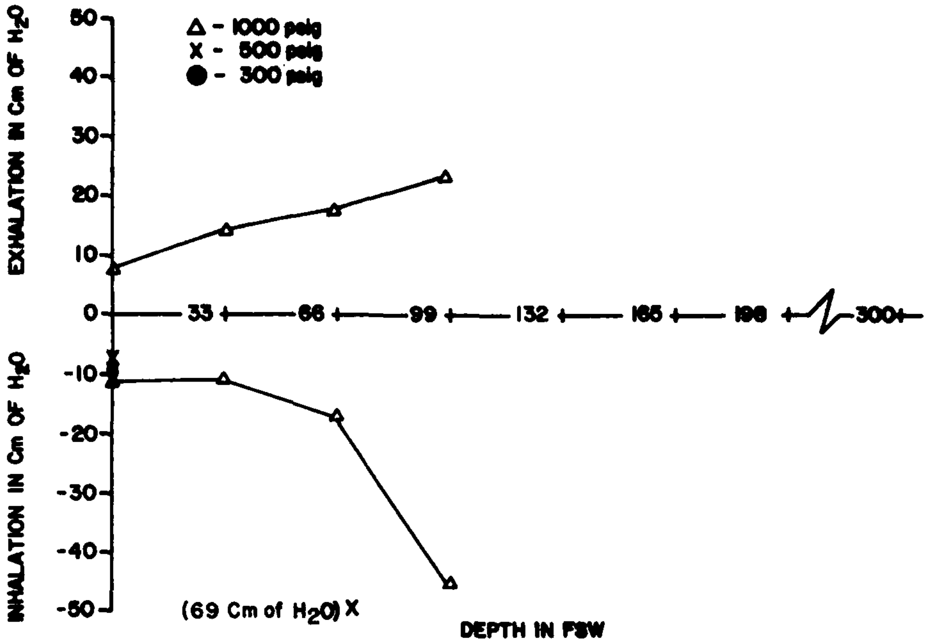

Figure 10B-5. Sub Aquatic Systems Sub X
Breathing resistance vs. depth at 90 RMV

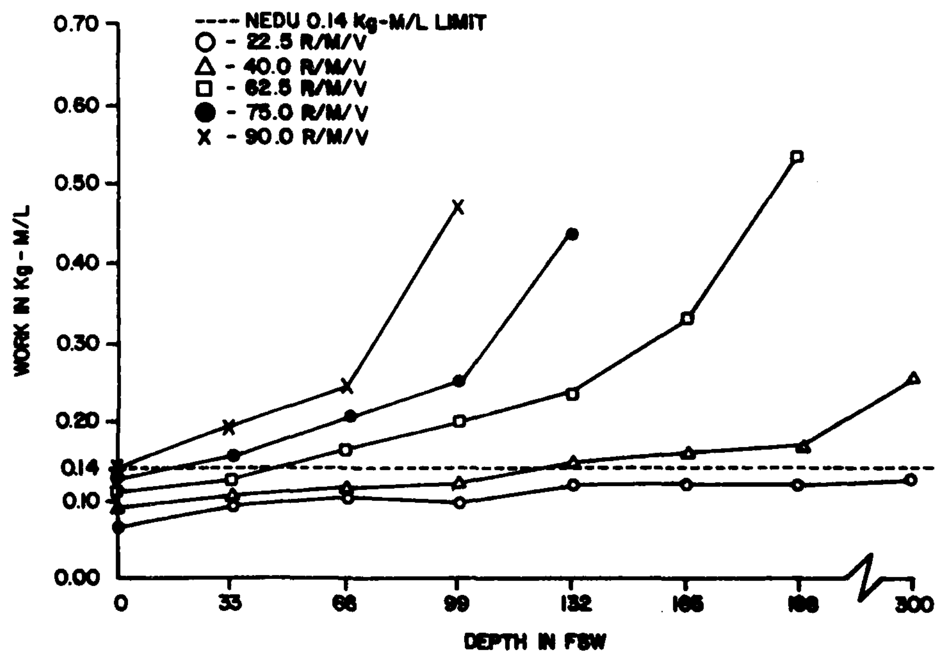

Figure 10B-6. Sub Aquatic Systems Sub X
Breathing work vs. depth at 1000 psig supply pressure

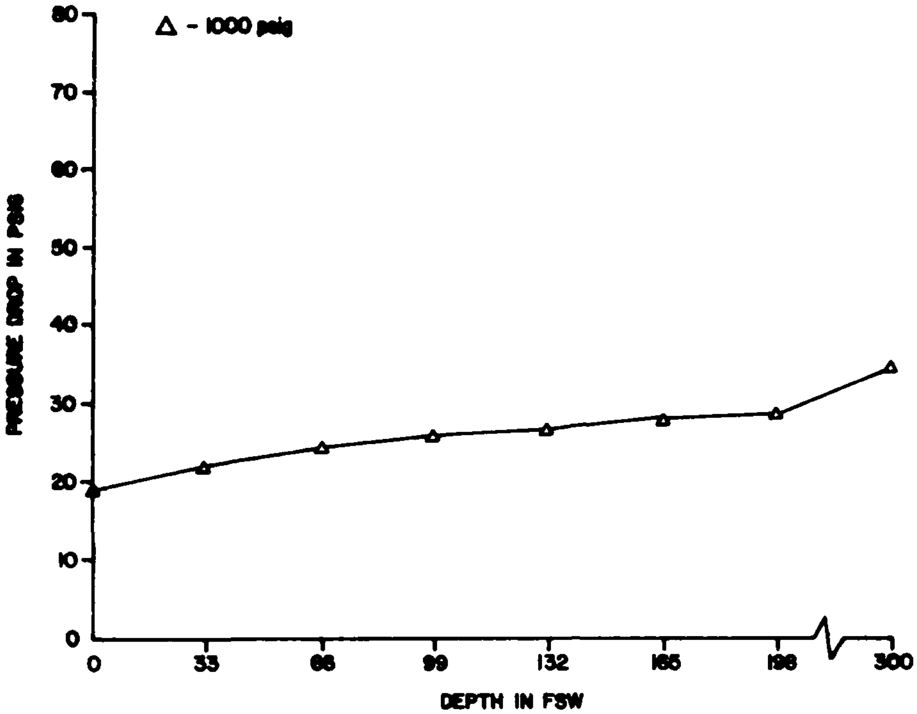

Figure 10B-7. Sub Aquatic Systems Sub X
First stage pressure drop vs. depth at 22.5 RMV

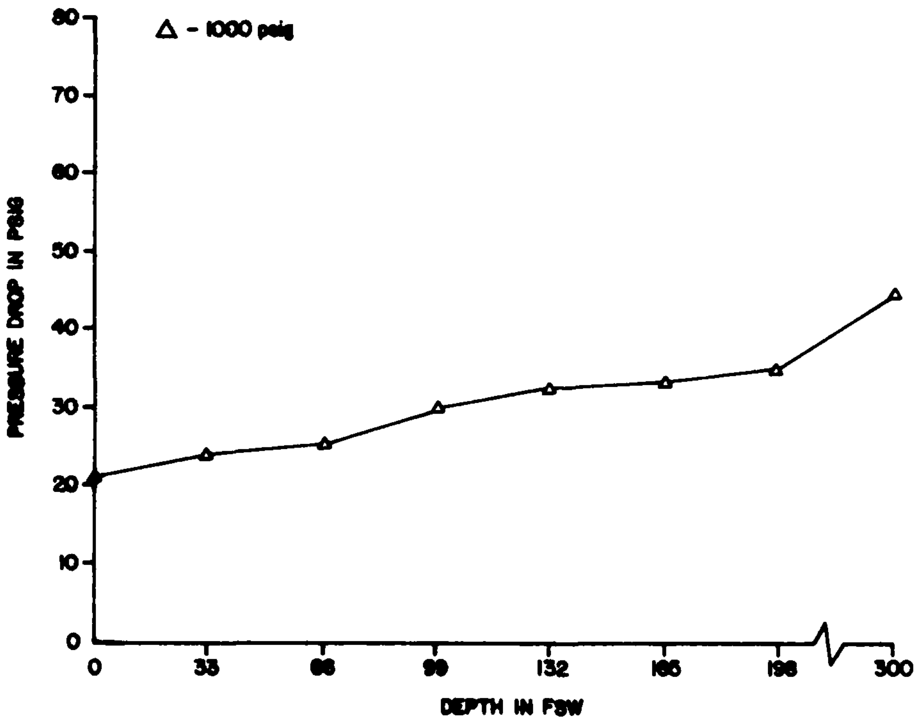

Figure 10B-8. Sub Aquatic Systems Sub X
First stage pressure drop vs. depth at 40 RMV

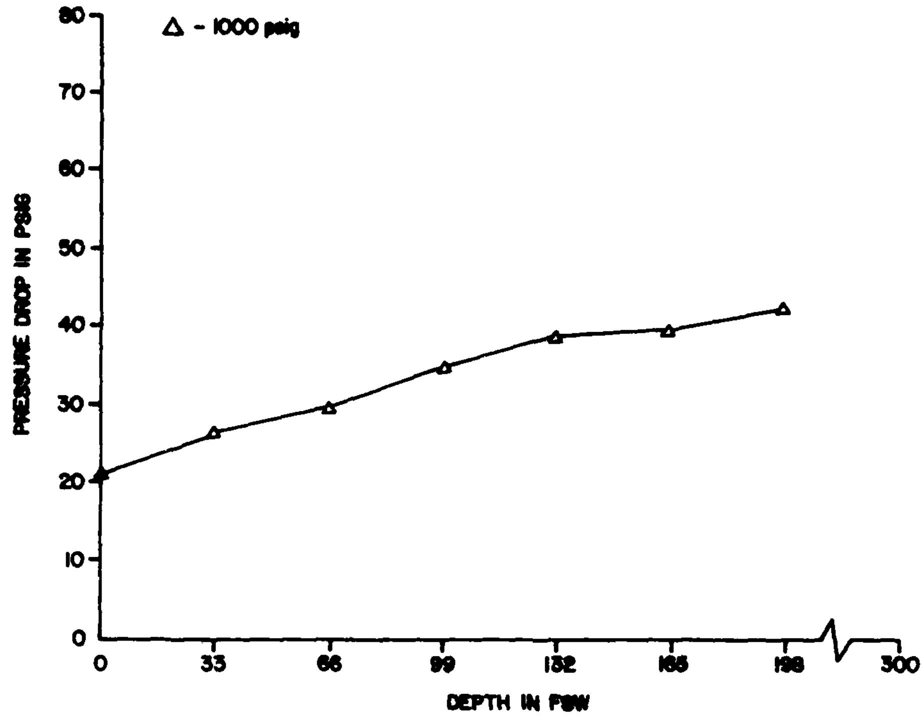

Figure 10B-9. Sub Aquatic Systems Sub X
First stage pressure drop vs. depth at 62.5 RMV

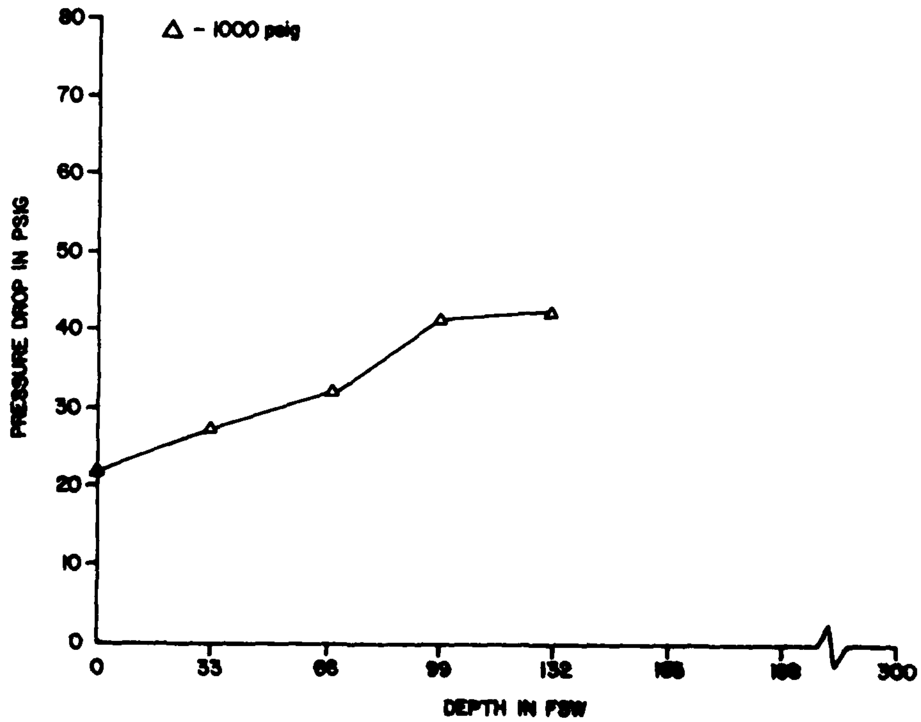

Figure 10B-10. Sub Aquatic Systems Sub X
First stage pressure drop vs. depth at 75 RMV

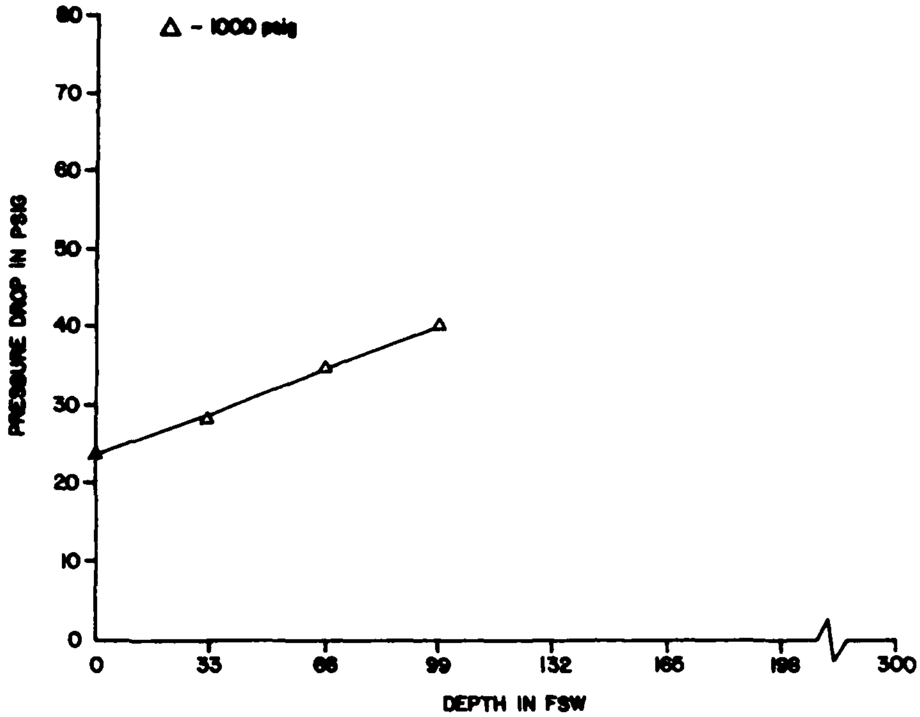

Figure 10B-11. Sub Aquatic Systems Sub X
First stage pressure drop vs. depth at 90 RMV

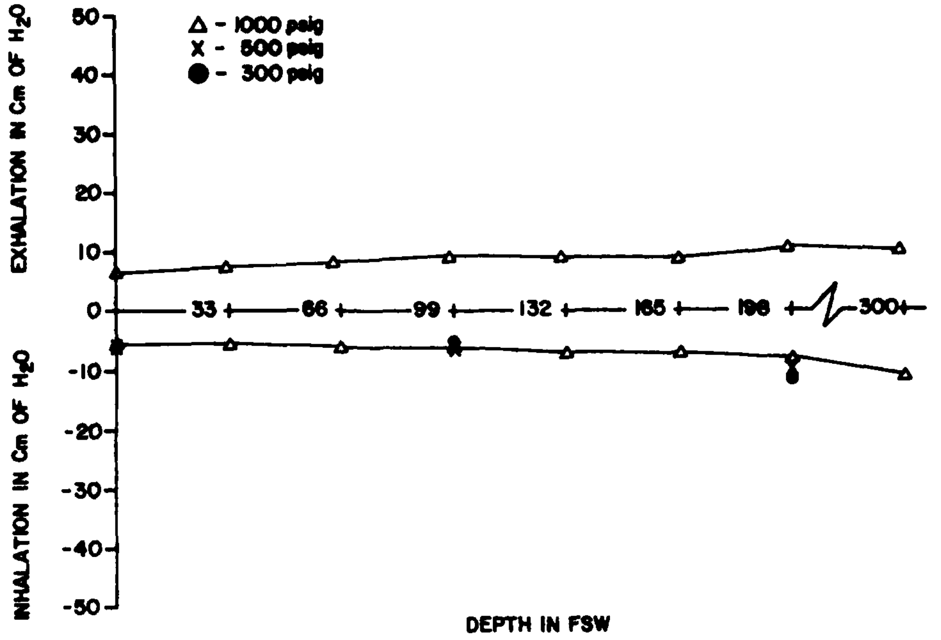

Figure 11A-1. Swimaster R14 Polaris
Breathing resistance vs. depth at 22.5 RMV

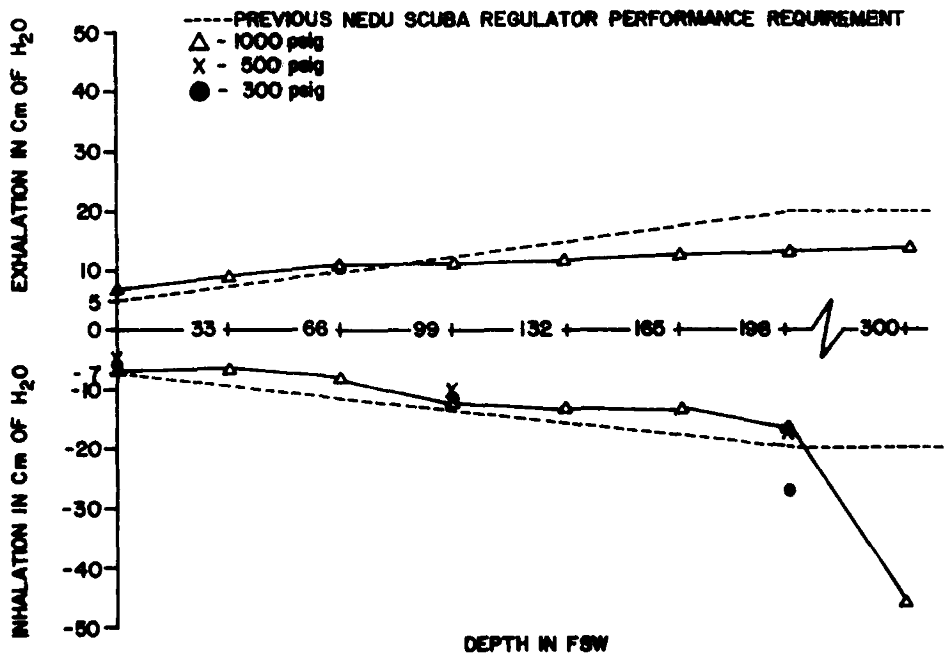

Figure 11A-2. Swimaster R14 Polaris
Breathing resistance vs. depth at 40 RMV

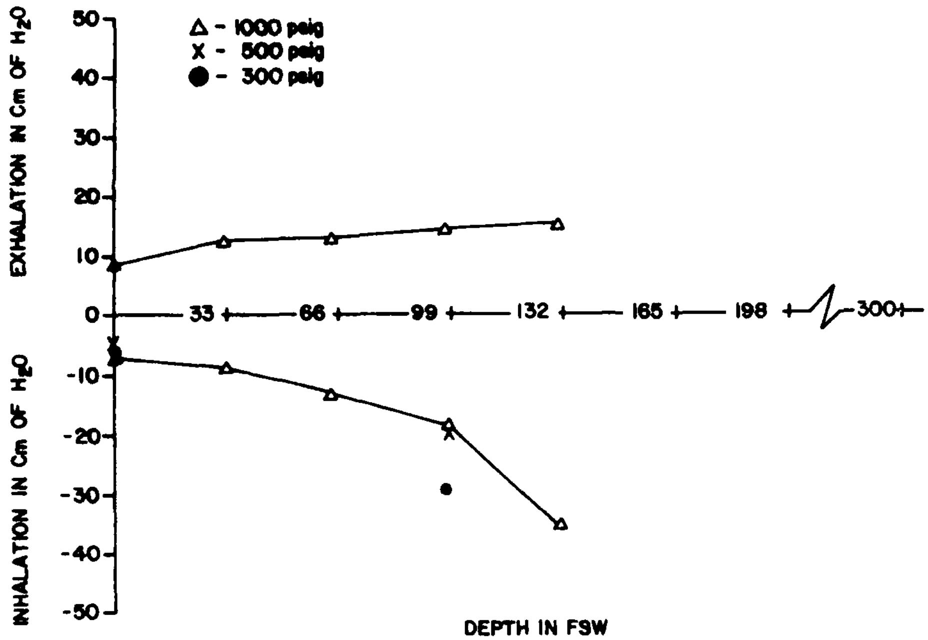

Figure 11A-3. Swimaster R14 Polaris
Breathing resistance vs. depth at 62.5 RMV

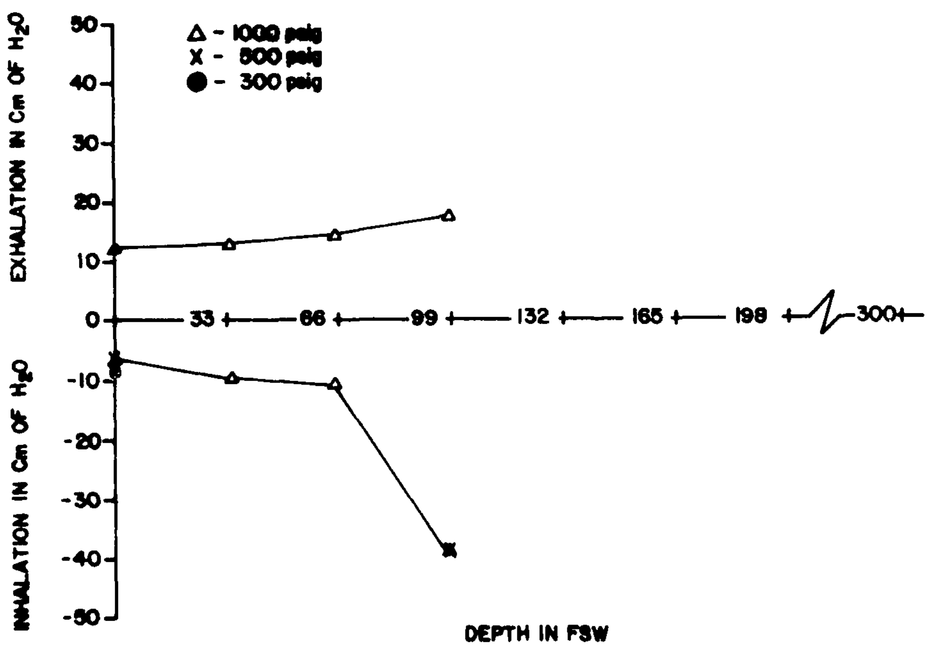

Figure 11A-4. Swimaster R14 Polaris
Breathing resistance vs. depth at 75 RMV

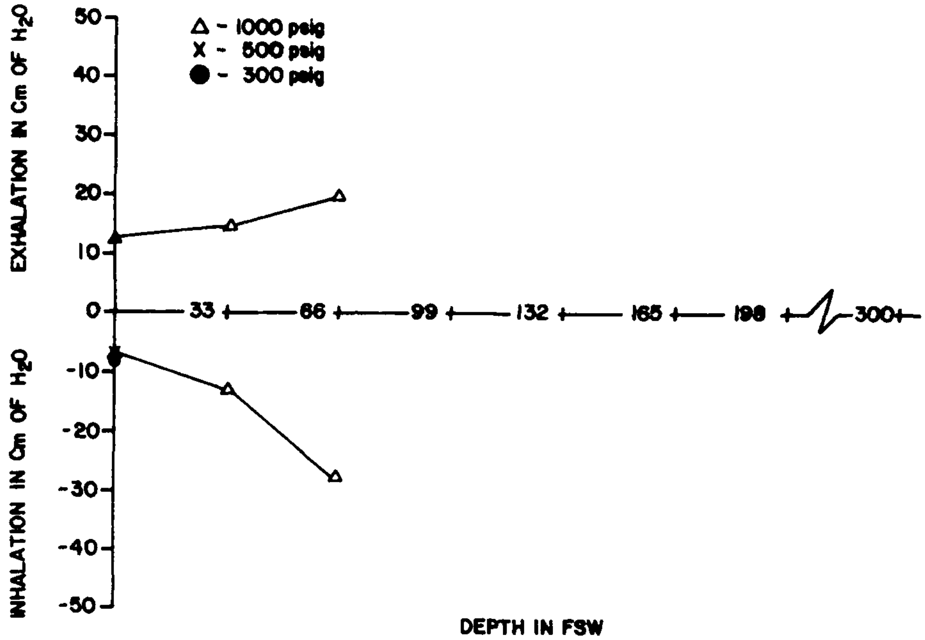

Figure 11A-5. Swimaster R14 Polaris
Breathing resistance vs. depth at 90 RMV

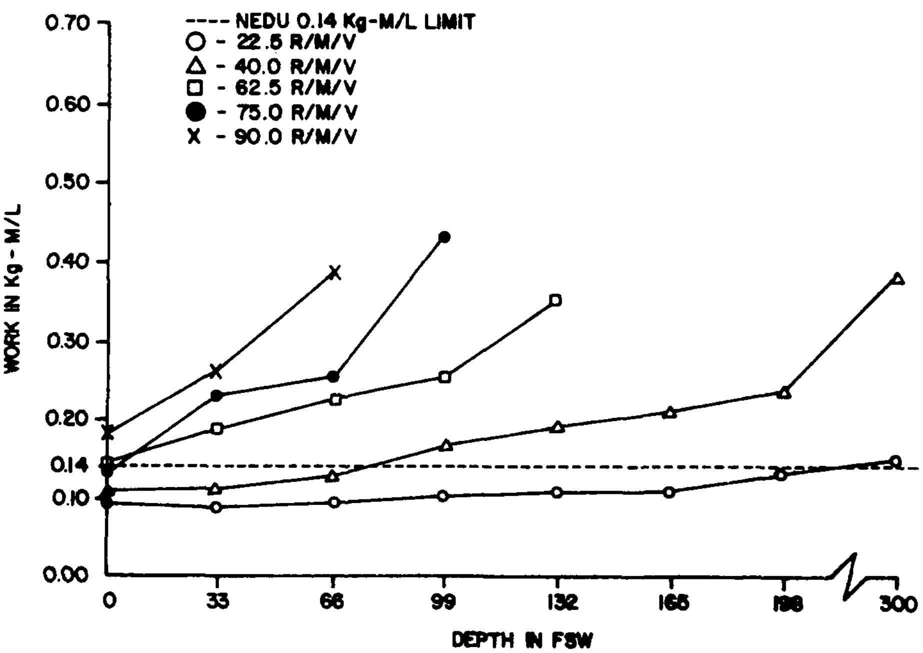

Figure 11A-6. Swimaster R14 Polaris
Breathing work vs. depth at 1000 psig supply pressure

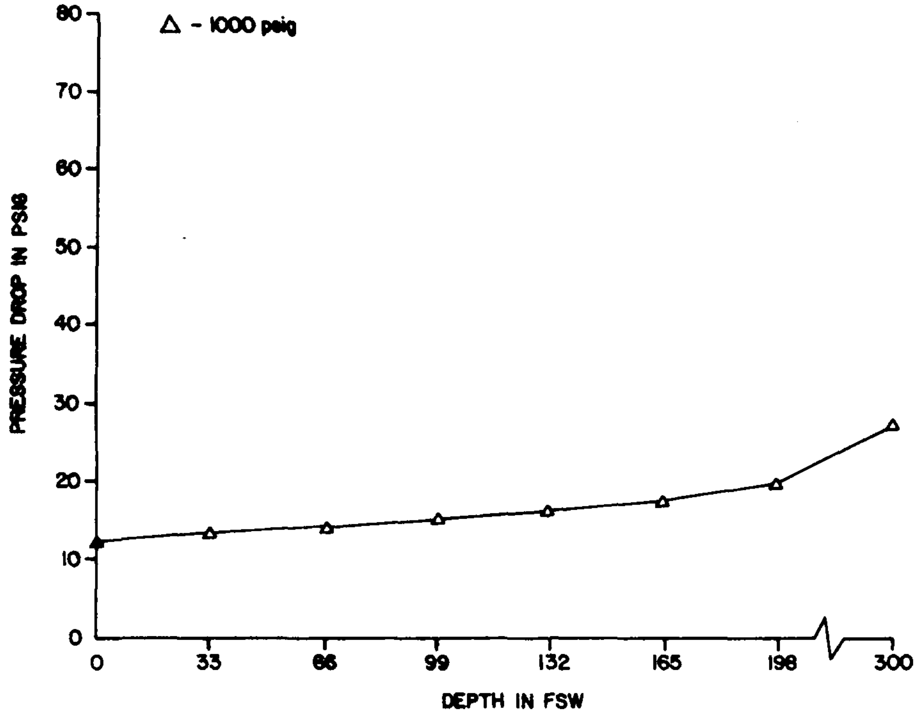

Figure 11A-7. Swimaster R14 Polaris
First stage pressure drop vs. depth at 22.5 RMV

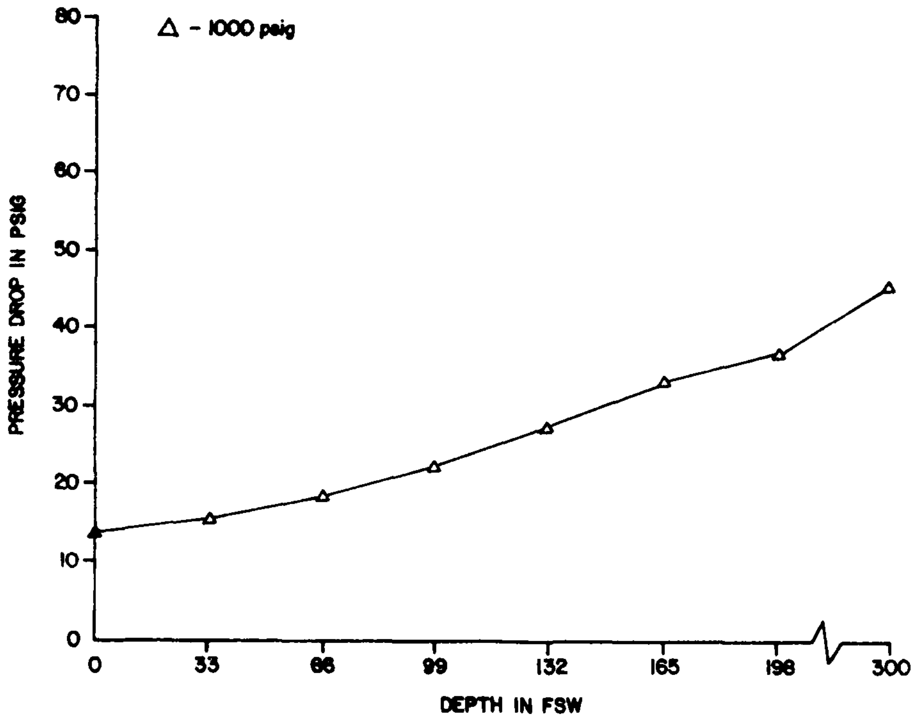

Figure 11A-8. Swimaster R14 Polaris
First stage pressure drop vs. depth at 40 RMV

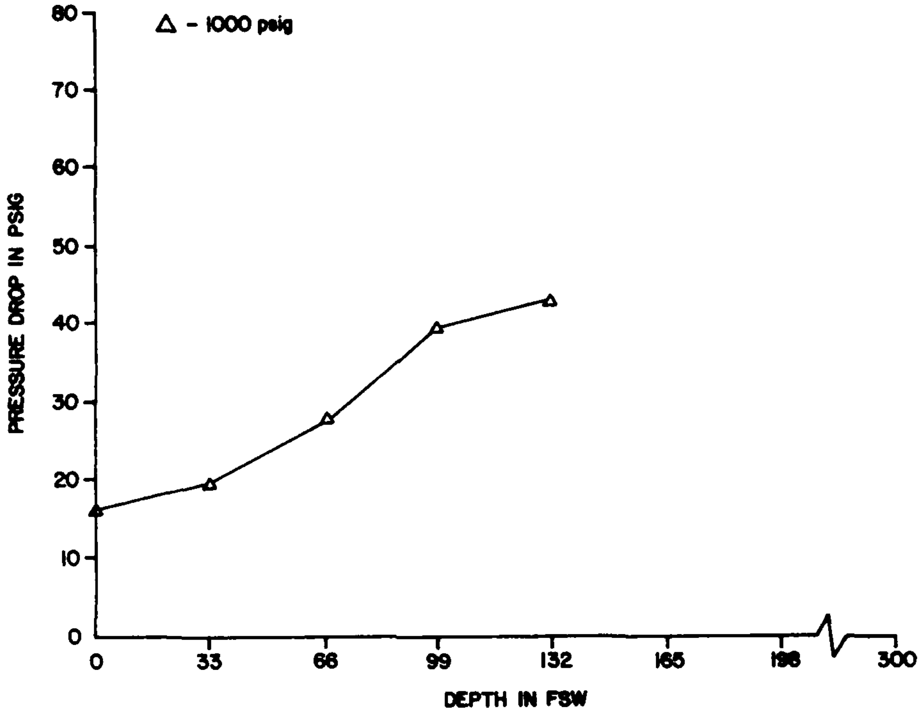

Figure 11A-9. Swimaster R14 Polaris
First stage pressure drop vs. depth at 62.5 RMV

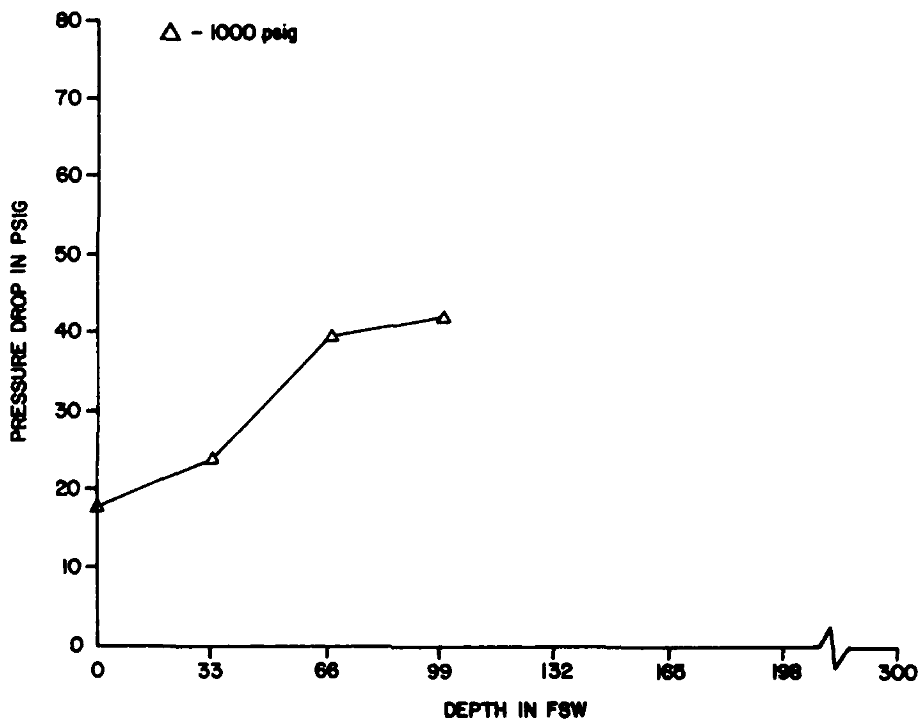

Figure 11A-10. Swimaster R14 Polaris
First stage pressure drop vs. depth at 75 RMV

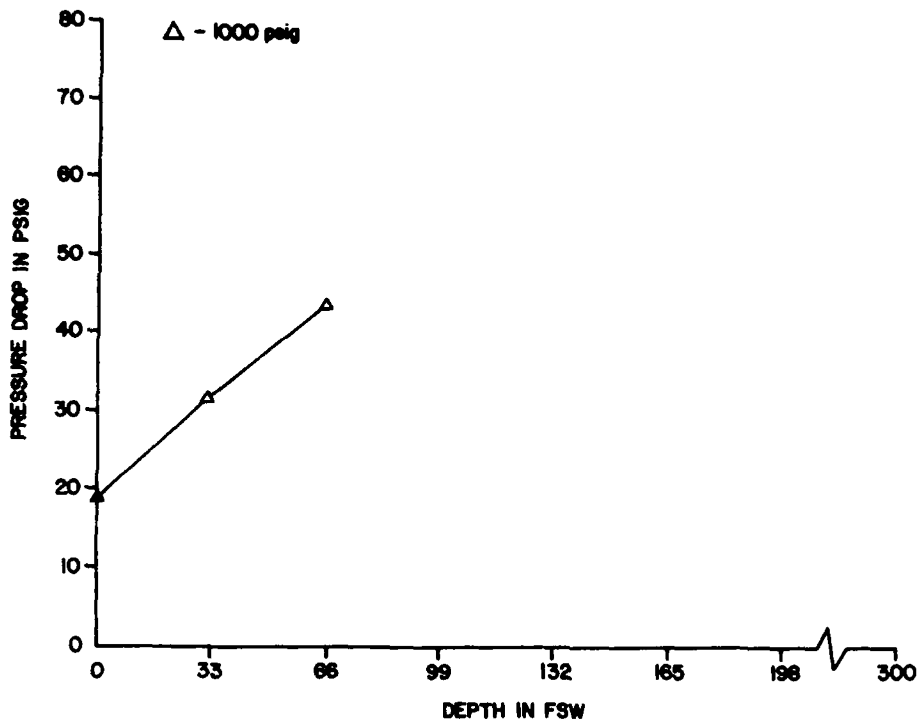

Figure 11A-11. Swimaster R14 Polaris
First stage pressure drop vs. depth at 90 RMV

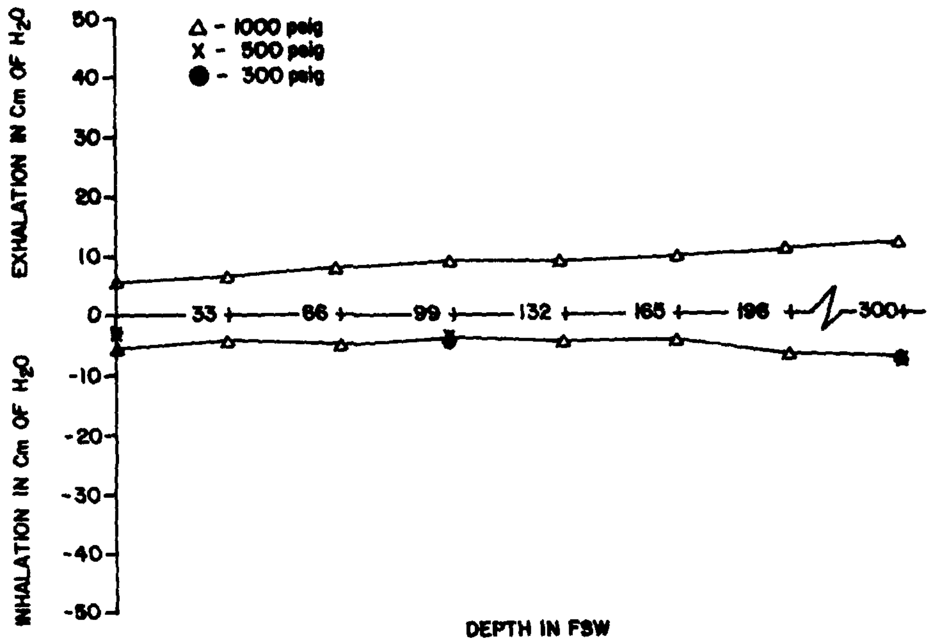

Figure 11B-1. Swimaster MR12
Breathing resistance vs. depth at 22.5 RMV

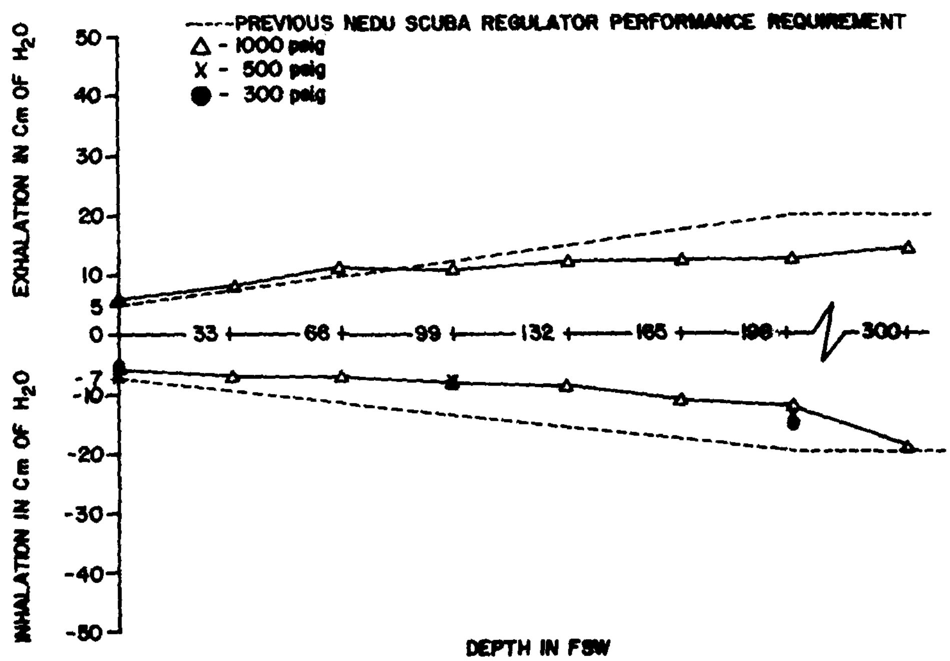

Figure 11B-2. Swimaster MR12
Breathing resistance vs. depth at 40 RMV

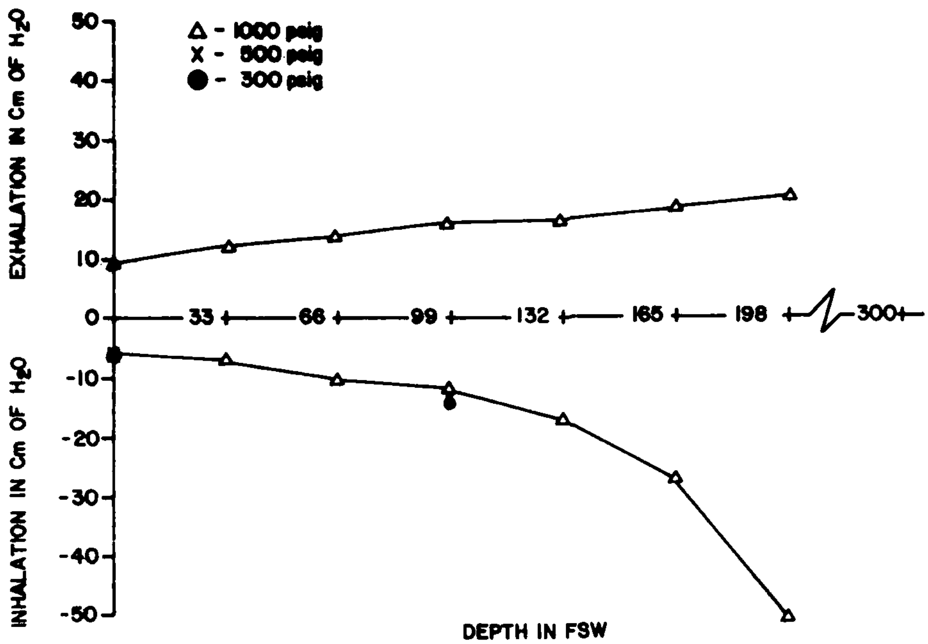

Figure 11B-3. Swimaster MR12
Breathing resistance vs. depth at 62.5 RMV

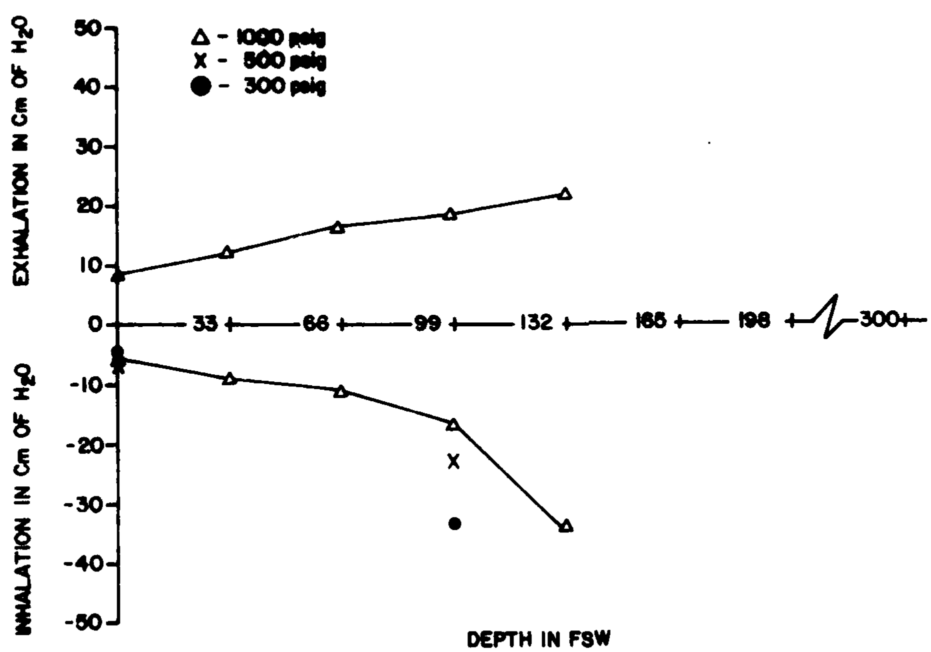

Figure 11B-4. Swimaster MR12
Breathing resistance vs. depth at 75 RMV

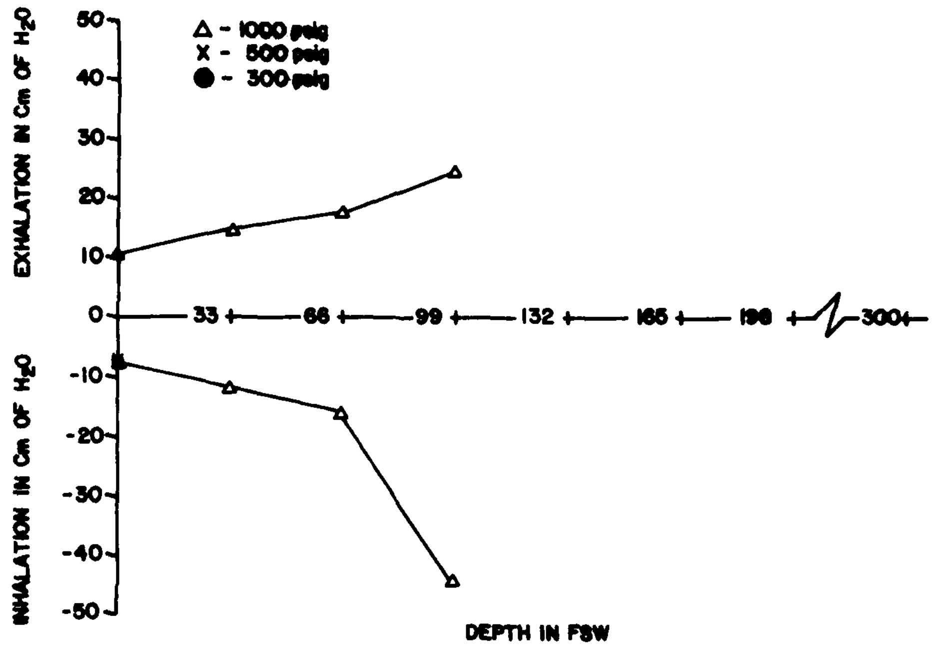

Figure 11B-5. Swimaster MR12
Breathing resistance vs. depth at 90 RMV

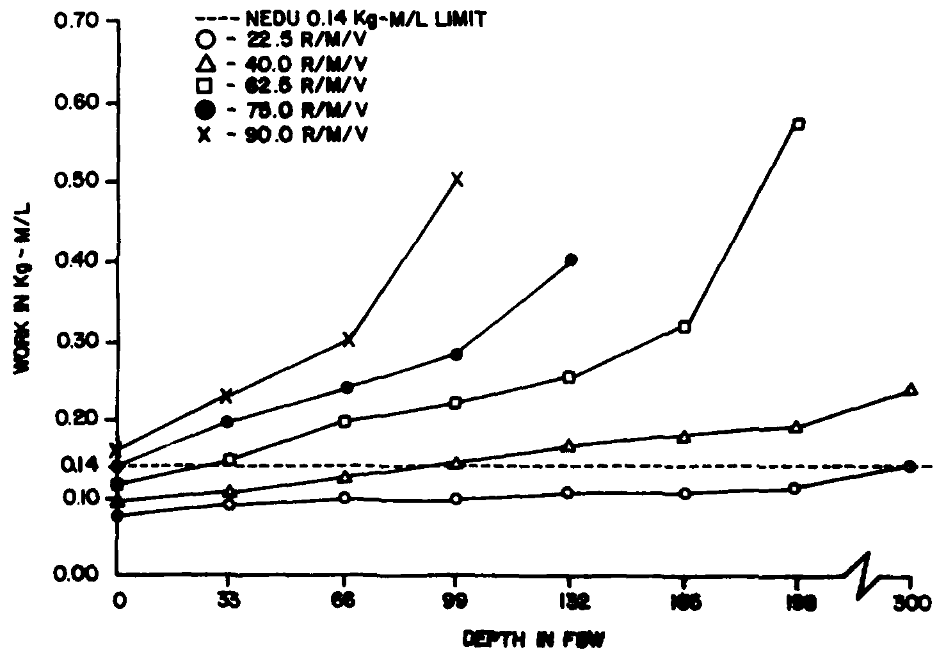

Figure 11B-6. Swimaster MR12
Breathing work vs. depth at 1000 psig supply pressure

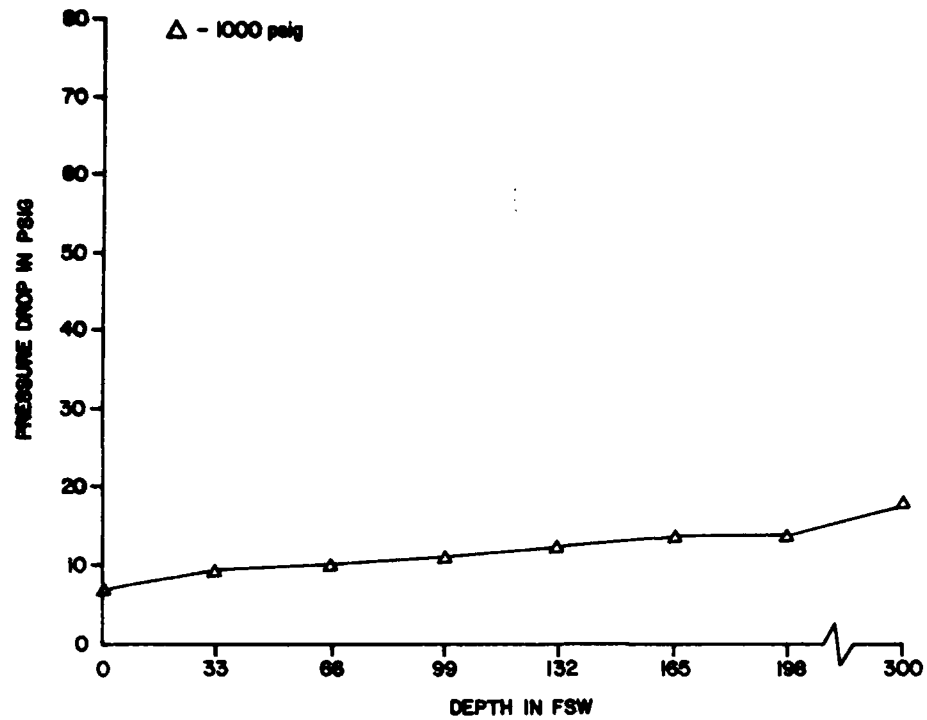

Figure 11B-7. Swimaster MR12
First stage pressure drop vs. depth at 22.5 RMV

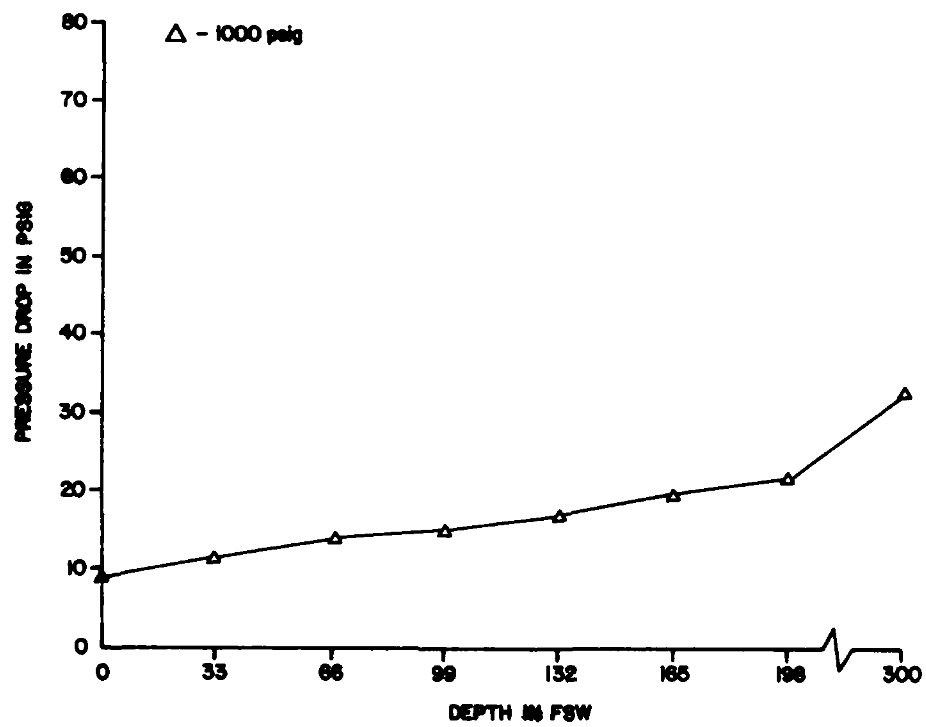

Figure 11B-8. Swimaster MR12
First stage pressure drop vs. depth at 40 RMV

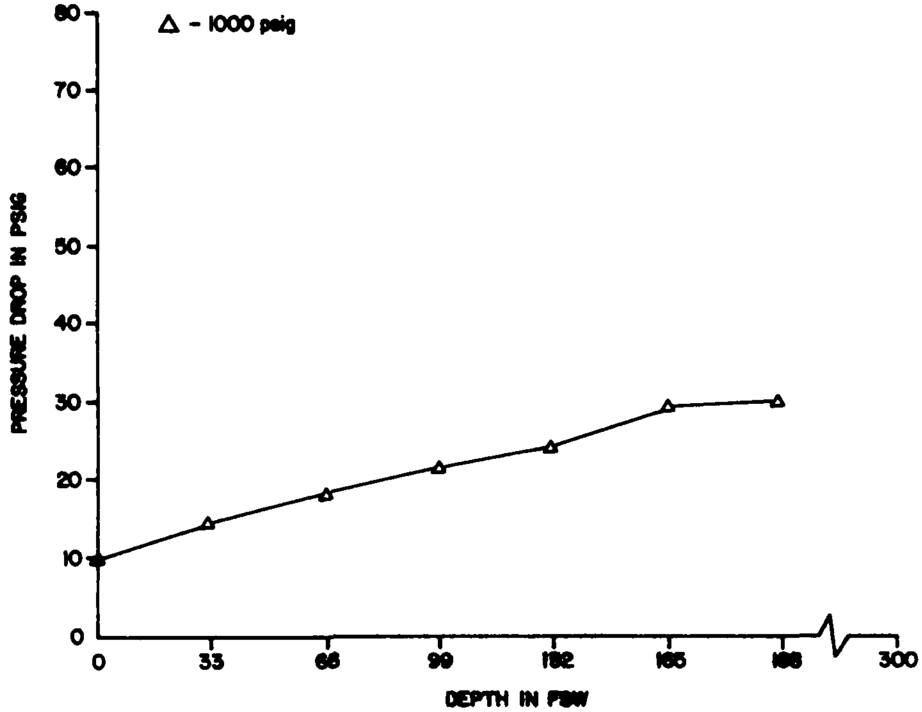

Figure 11B-9. Swimaster MR12
First stage pressure drop vs. depth at 62.5 RMV

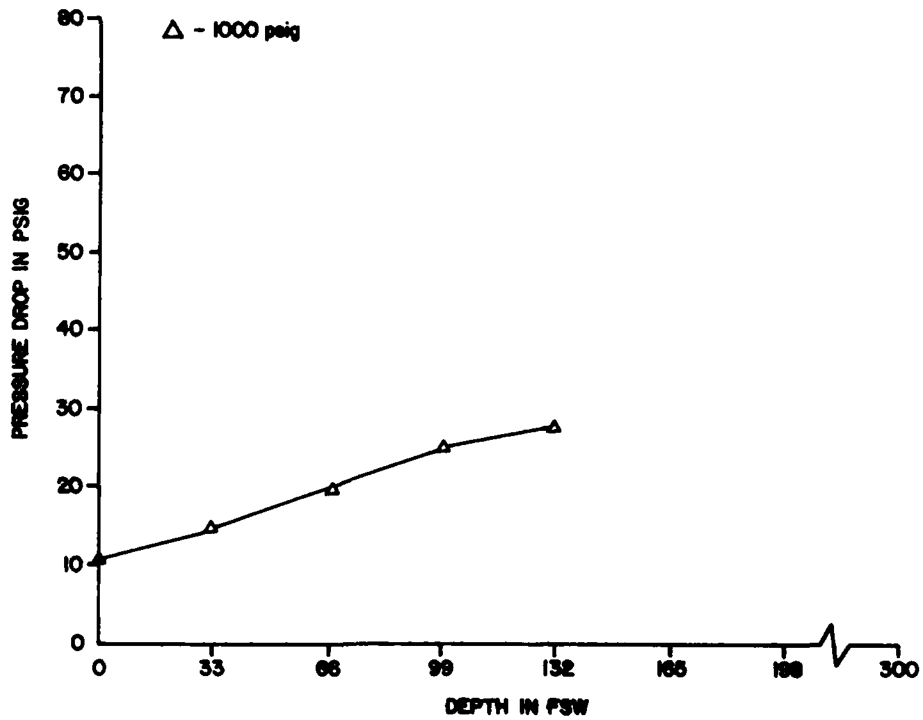

Figure 11B-10. Swimaster MR12
First stage pressure drop vs. depth at 75 RMV

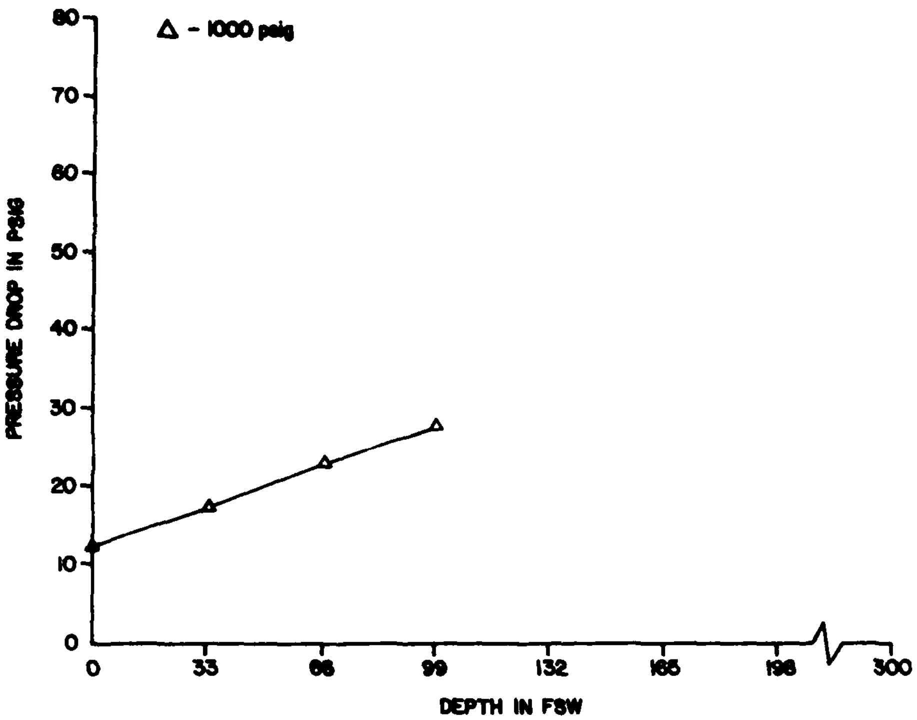

Figure 11B-11. Swimaster MR12
First stage pressure drop vs. depth at 90 RMV

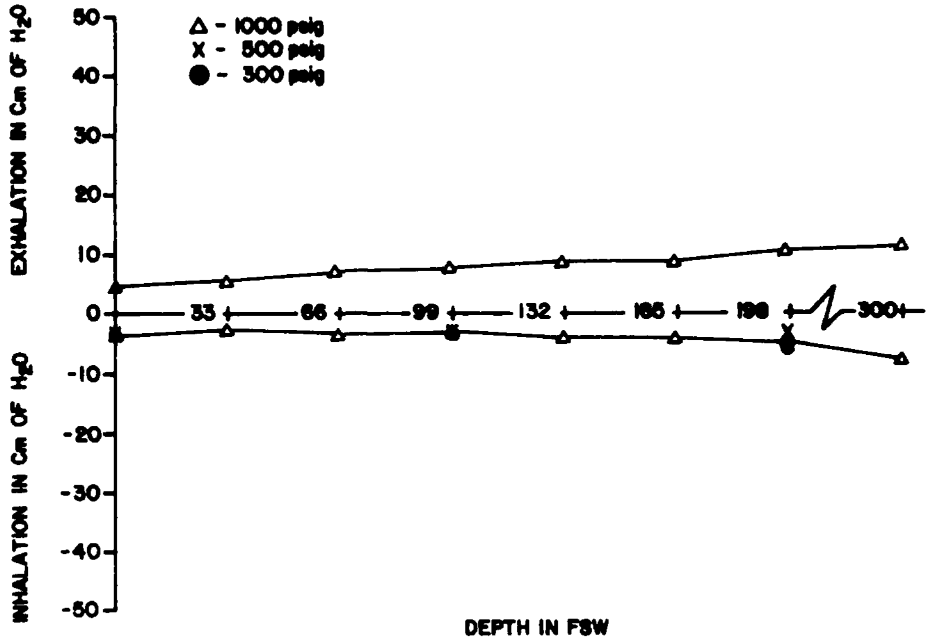

Figure 11C-1. Swimaster MR12-II
Breathing resistance vs. depth at 22.5 RMV

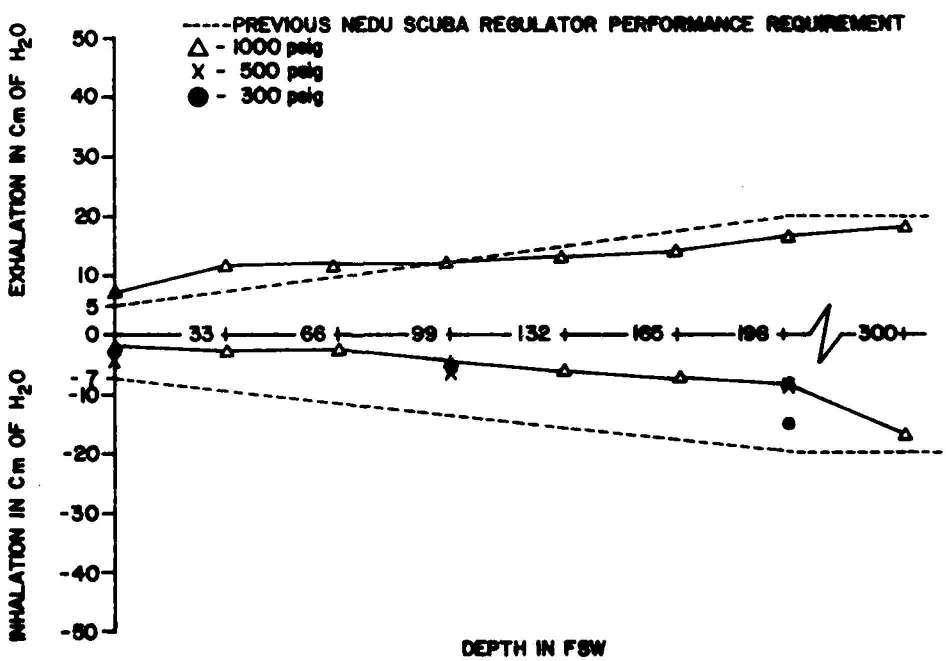

Figure 11C-2. Swimaster MR12-II
Breathing resistance vs. depth at 40 RMV

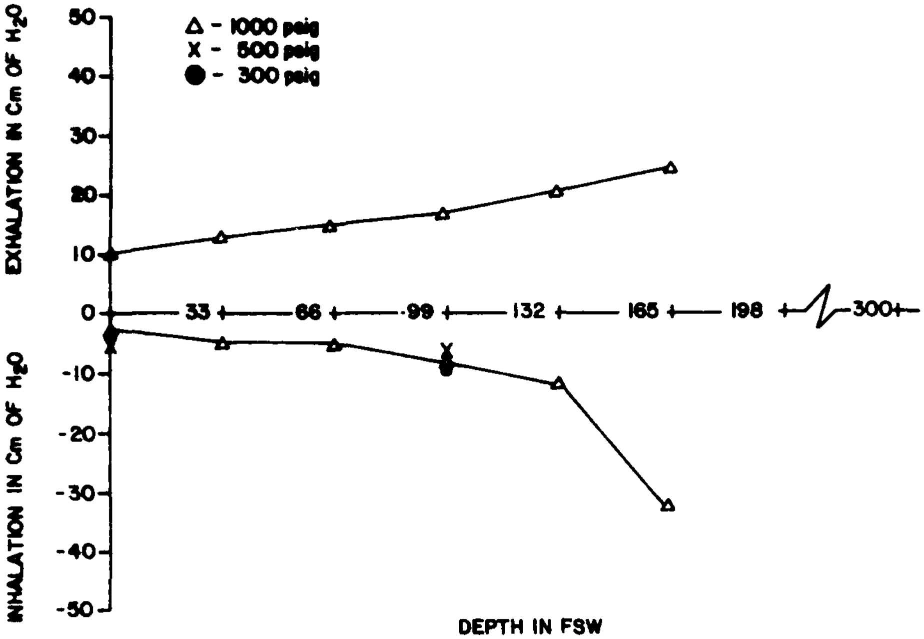

Figure 11C-3. Swimaster MR12-II
Breathing resistance vs. depth at 62.5 RMV

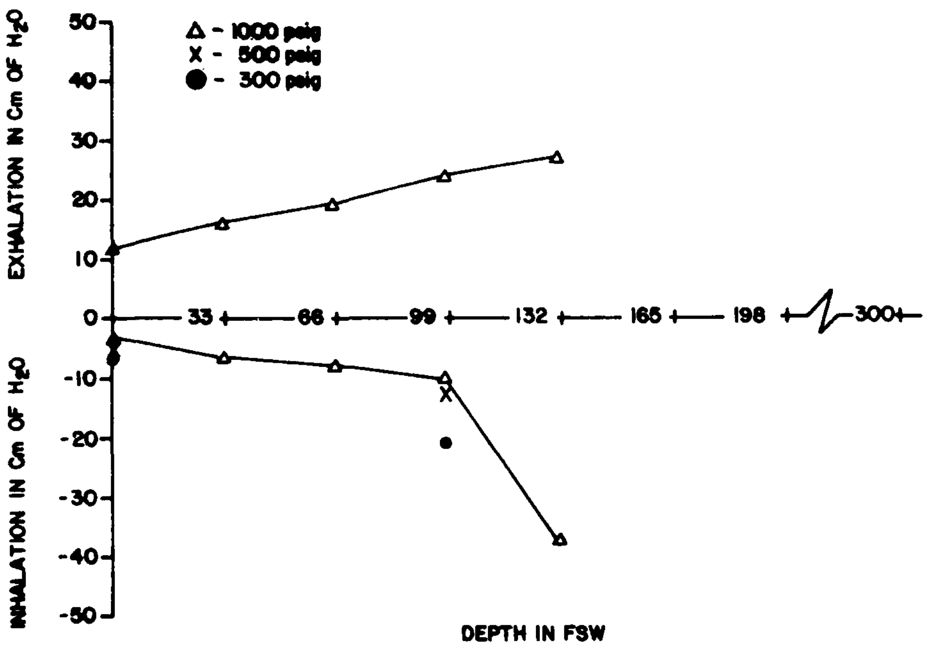

Figure 11C-4. Swimaster MR12-II
Breathing resistance vs. depth at 75 RMV

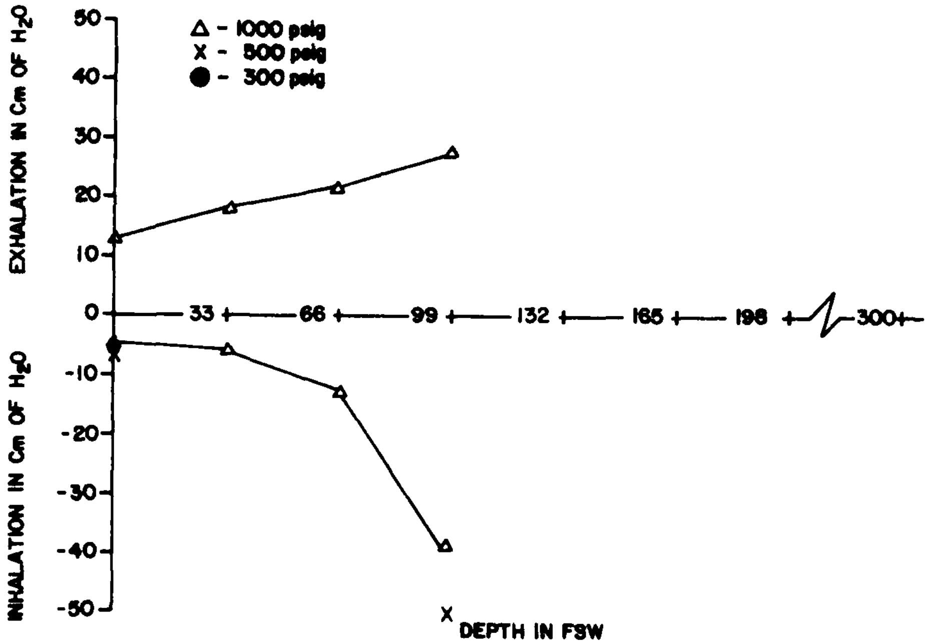

Figure 11C-5. Swimaster MR12-II
Breathing resistance vs. depth at 90 RMV

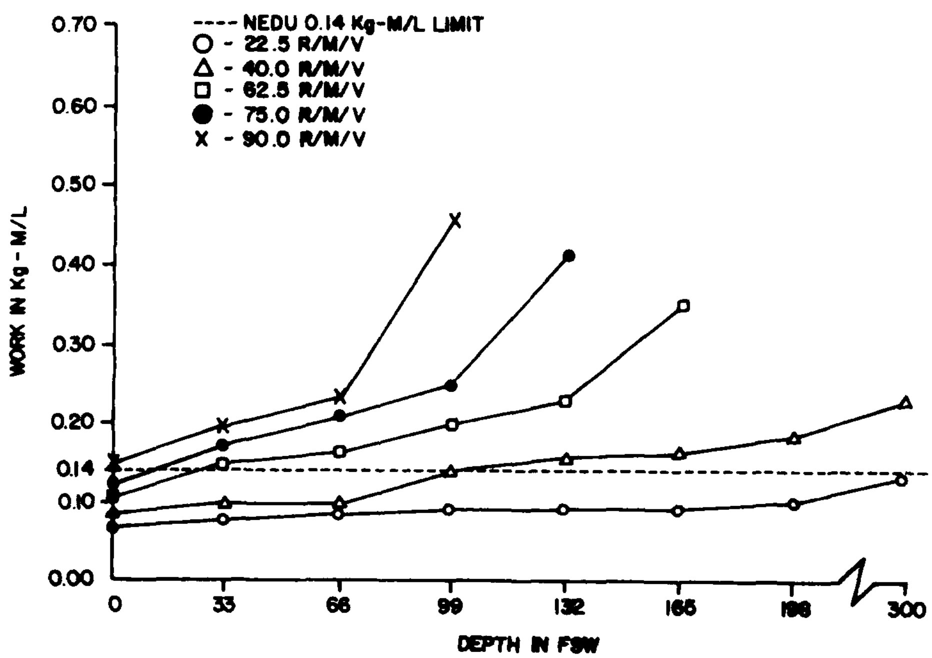

Figure 11C-6. Swimaster MR12-II
Breathing work vs. depth at 1000 psig supply pressure

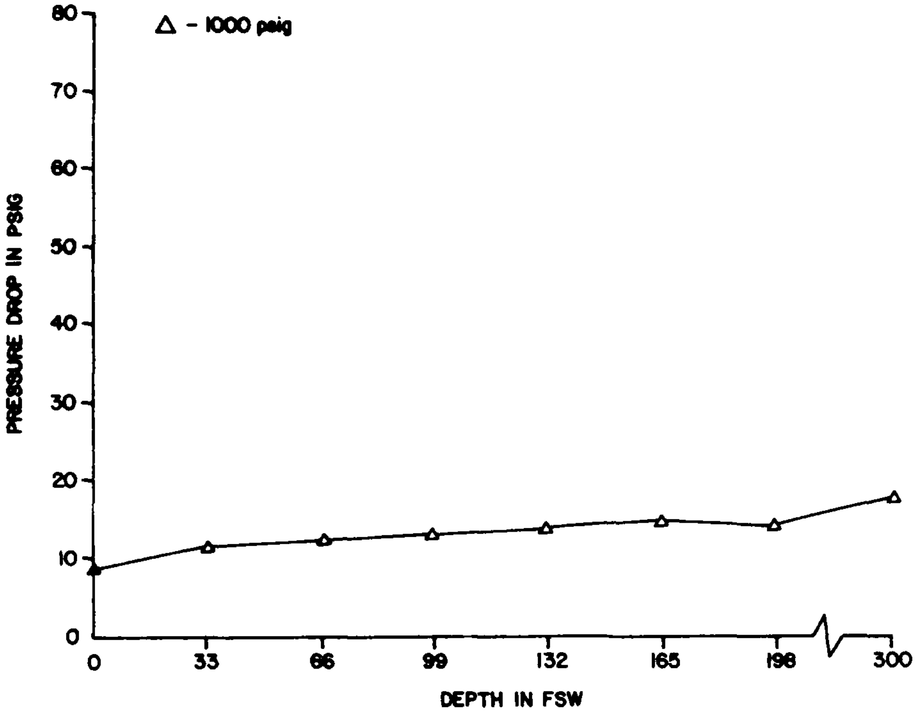

Figure 11C-7. Swimaster MR12-II
First stage pressure drop vs. depth at 22.5 RMV

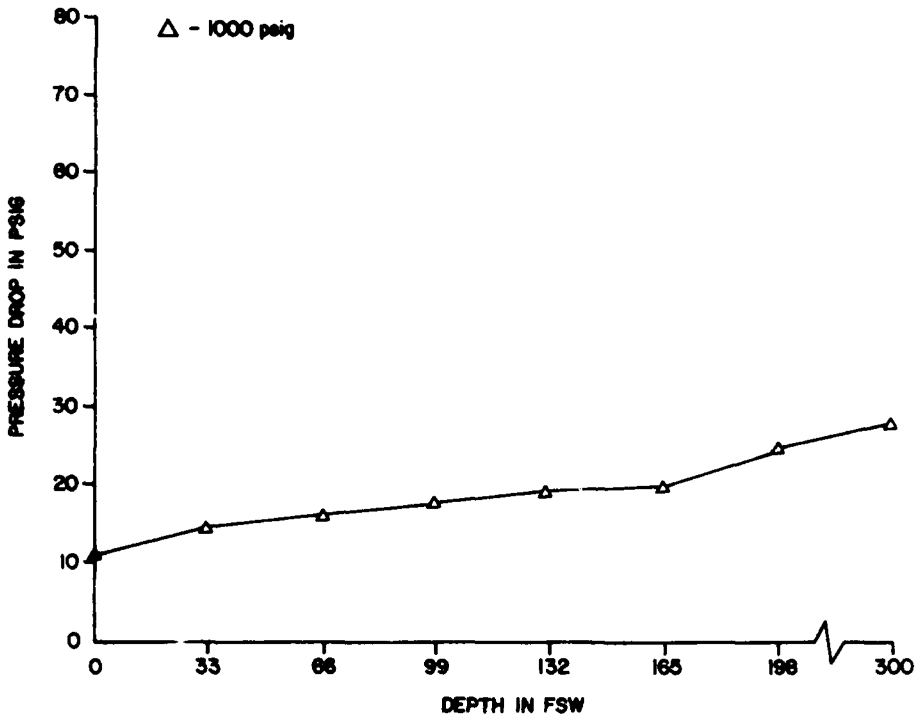

Figure 11C-8. Swimaster MR12-II
First stage pressure drop vs. depth at 40 RMV

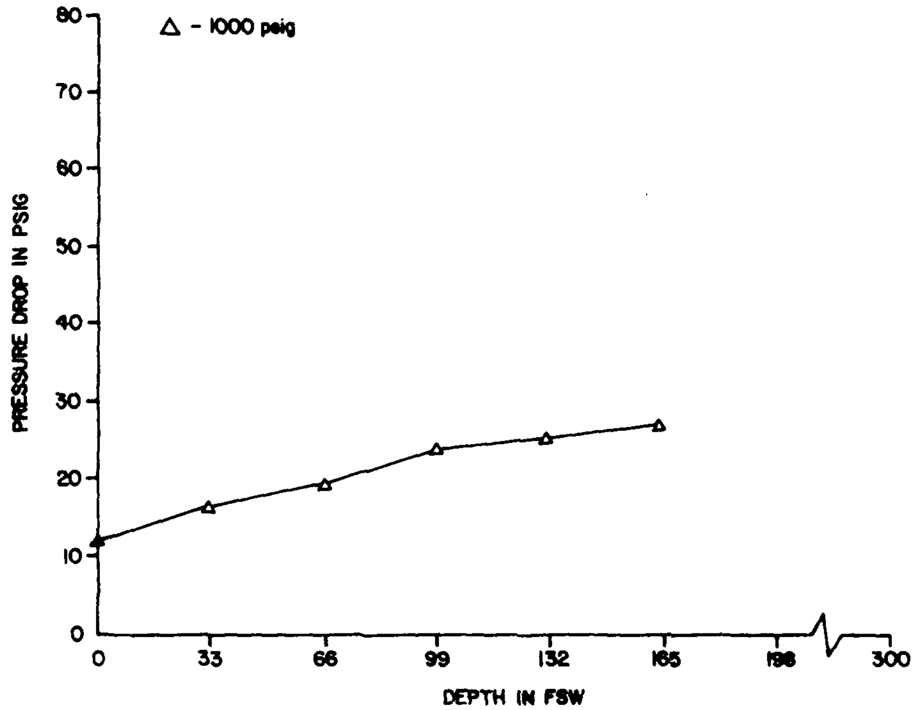

Figure 11C-9. Swimaster MR12-II
First stage pressure drop vs. depth at 62.5 RMV

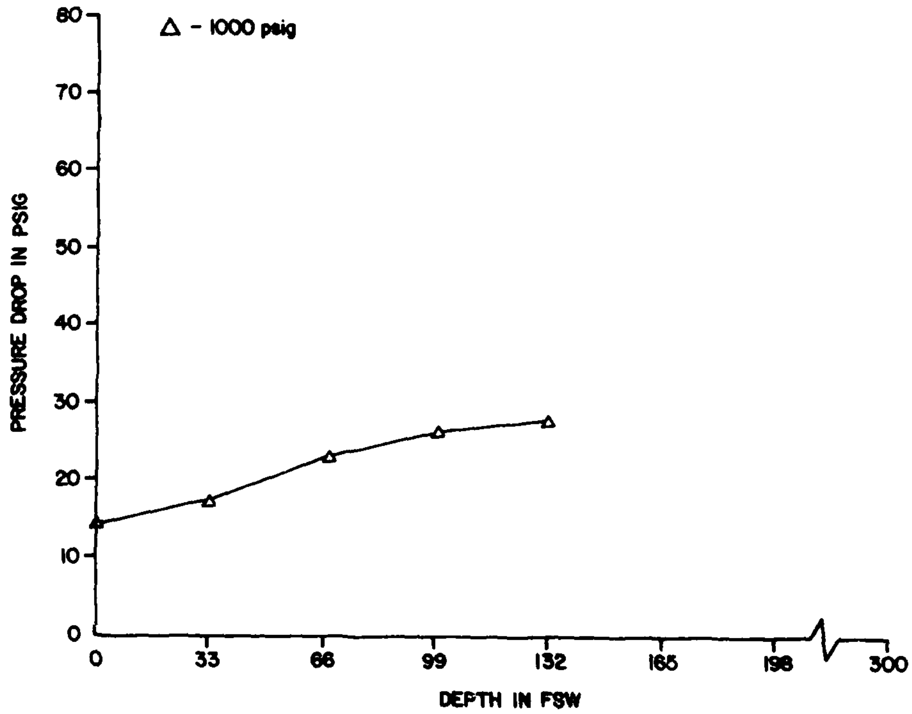

Figure 11C-10. Swimaster MR12-II
First stage pressure drop vs. depth at 75 RMV

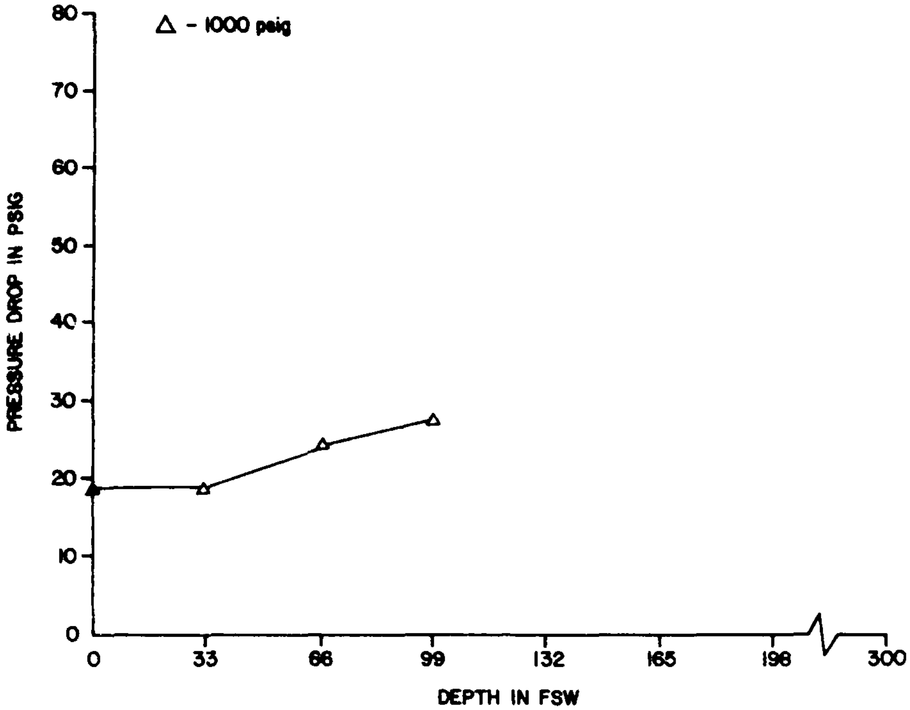

Figure 11C-11. Swimaster MR12-II
First stage pressure drop vs. depth at 90 RMV

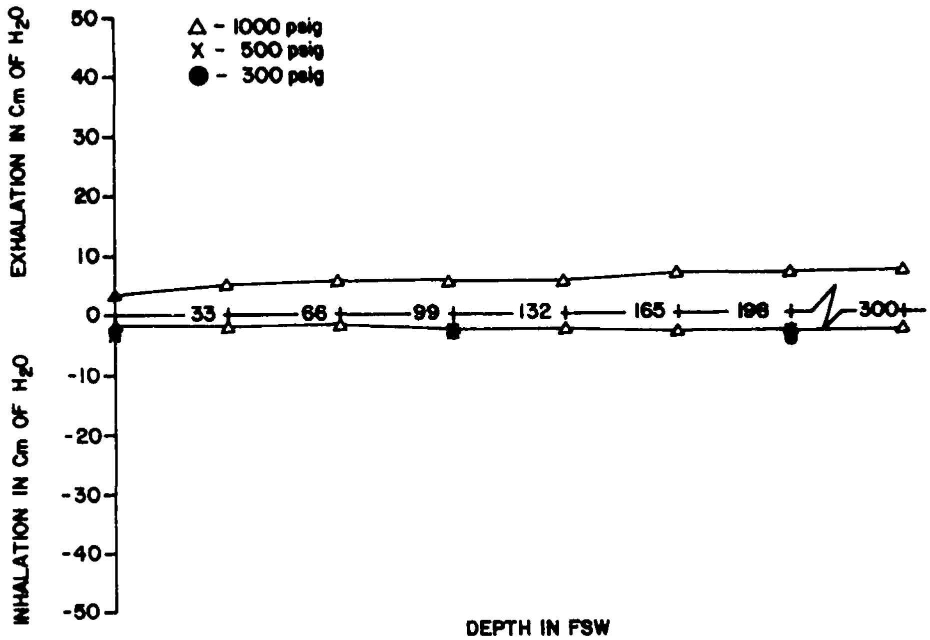

Figure 12A-1. Tekna T-2100
Breathing resistance vs. depth at 22.5 RMV

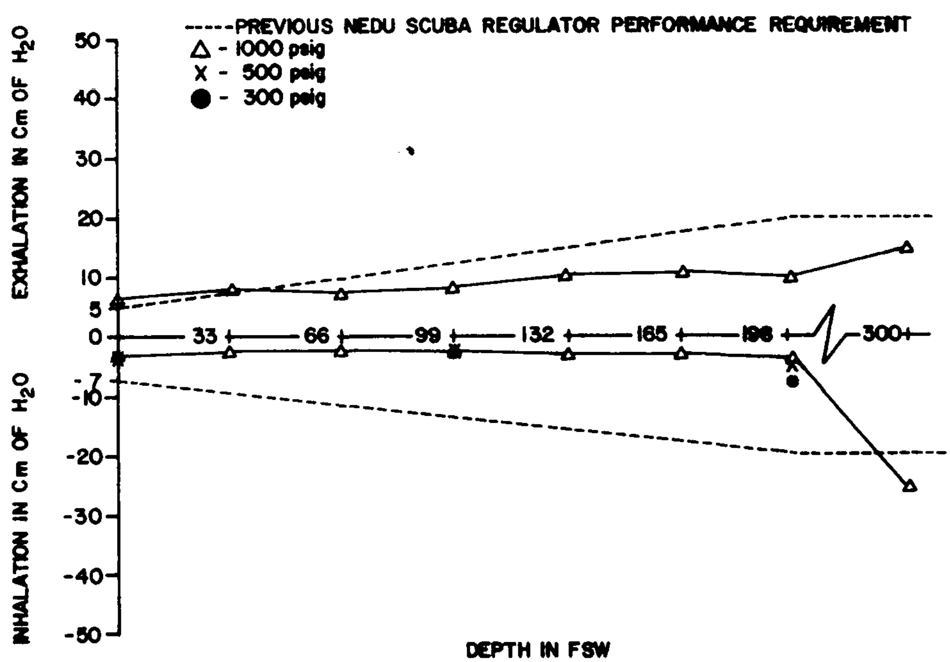

Figure 12A-2. Tekna T-2100
Breathing resistance vs. depth at 40 RMV

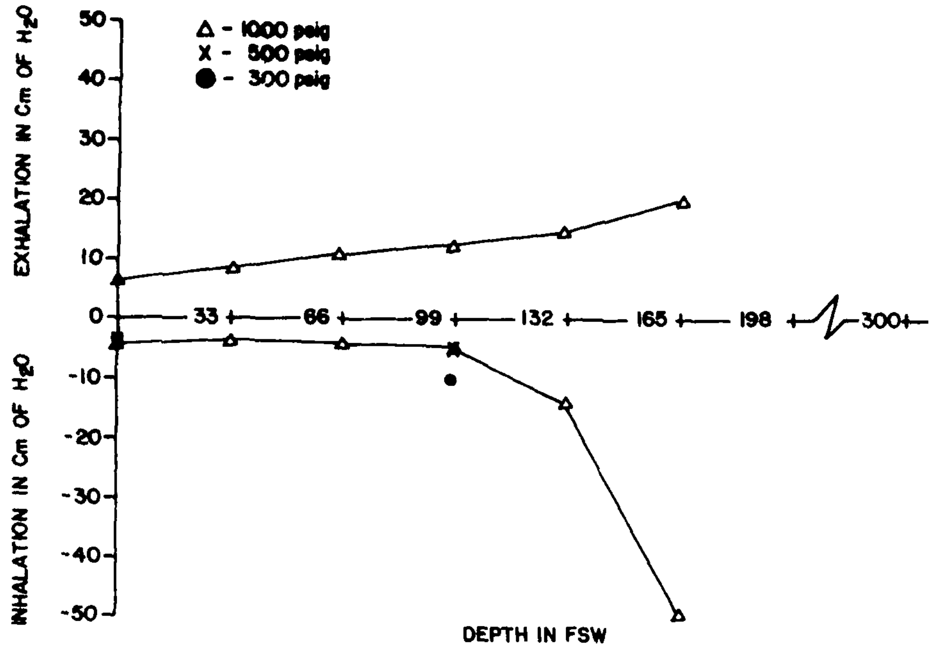

Figure 12A-3. Tekna T-2100
Breathing resistance vs. depth at 62.5 RMV

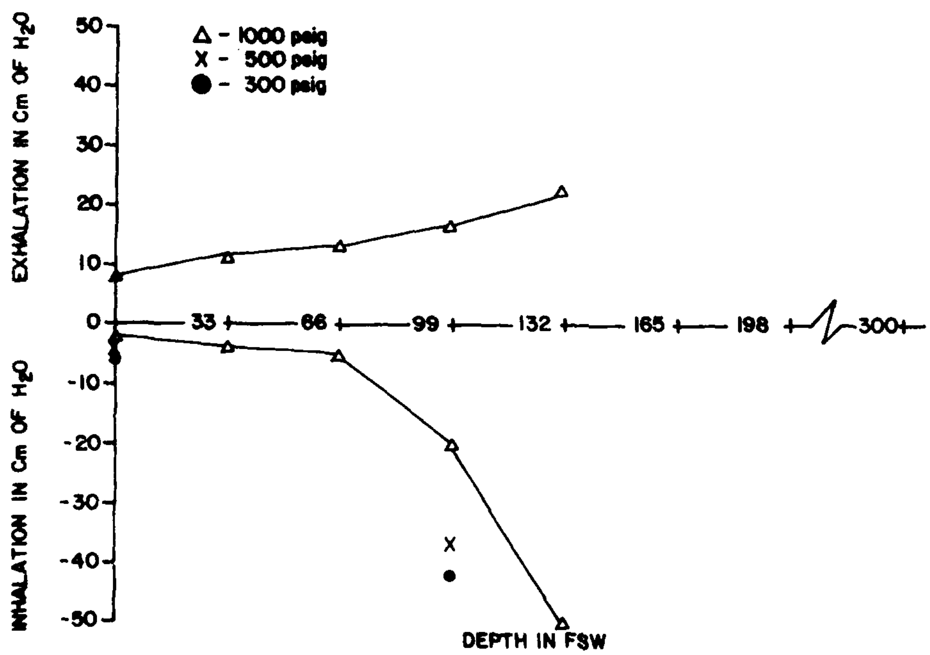

Figure 12A-4. Tekna T-2100
Breathing resistance vs. depth at 75 RMV

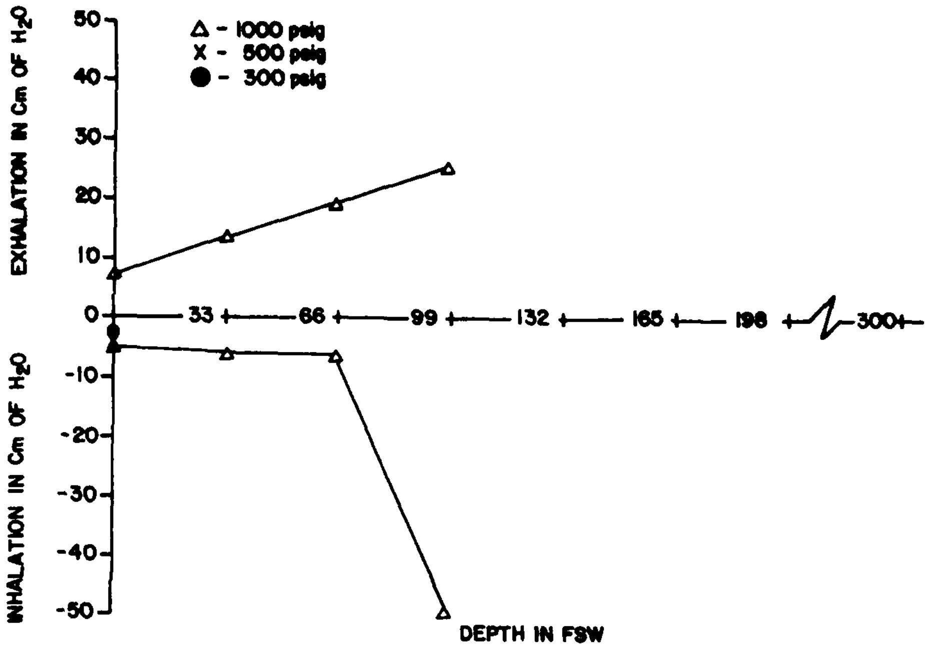

Figure 12A-5. Tekna T-2100
Breathing resistance vs. depth at 90 RMV

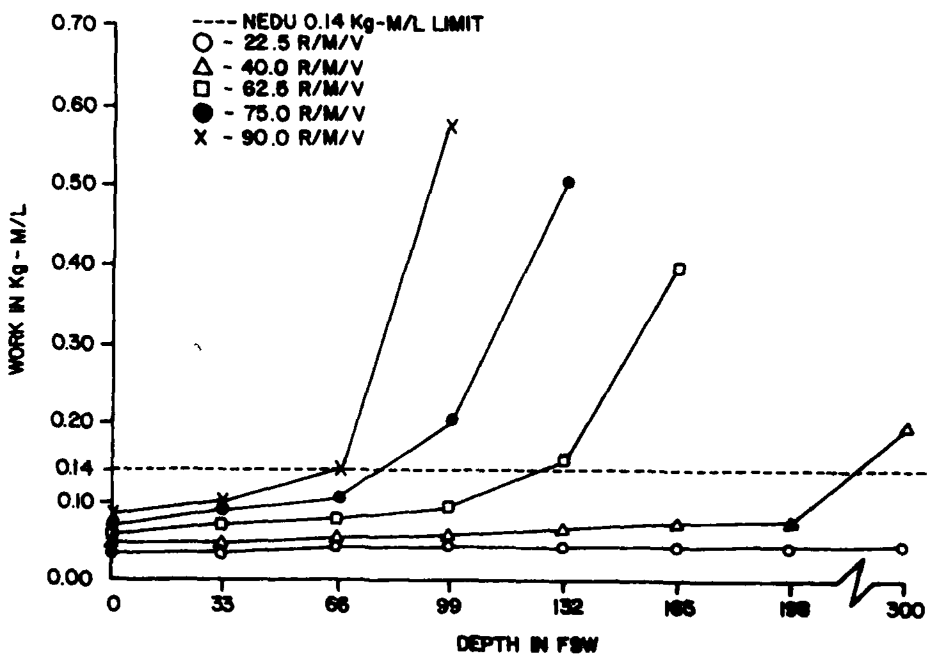

Figure 12A-6. Tekna T-2100
Breathing work vs. depth at 1000 psig supply pressure

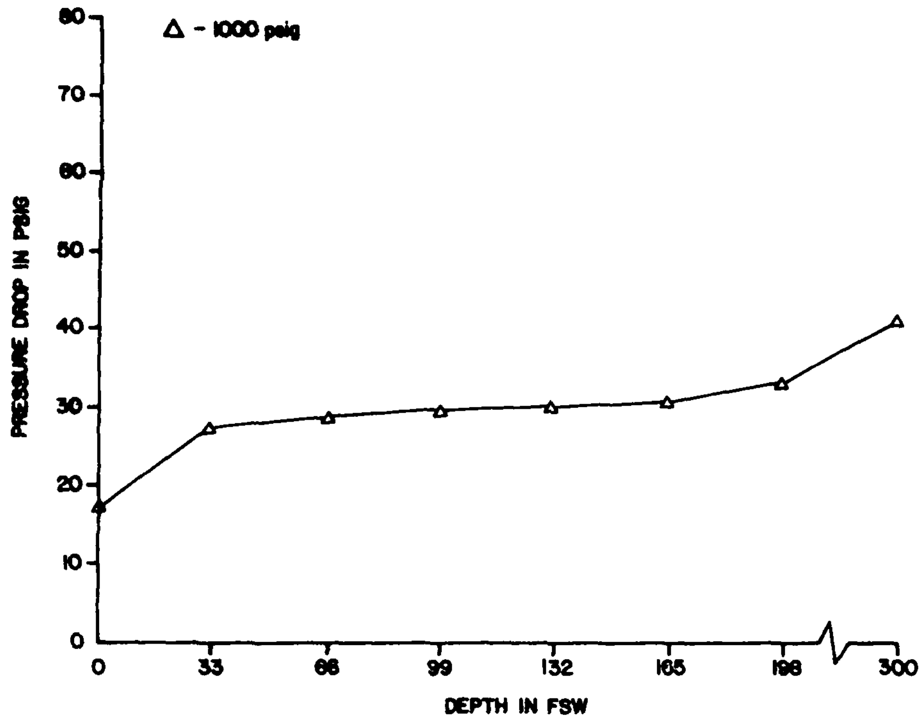

Figure 12A-7. Tekna T-2100
First stage pressure drop vs. depth at 22.5 RMV

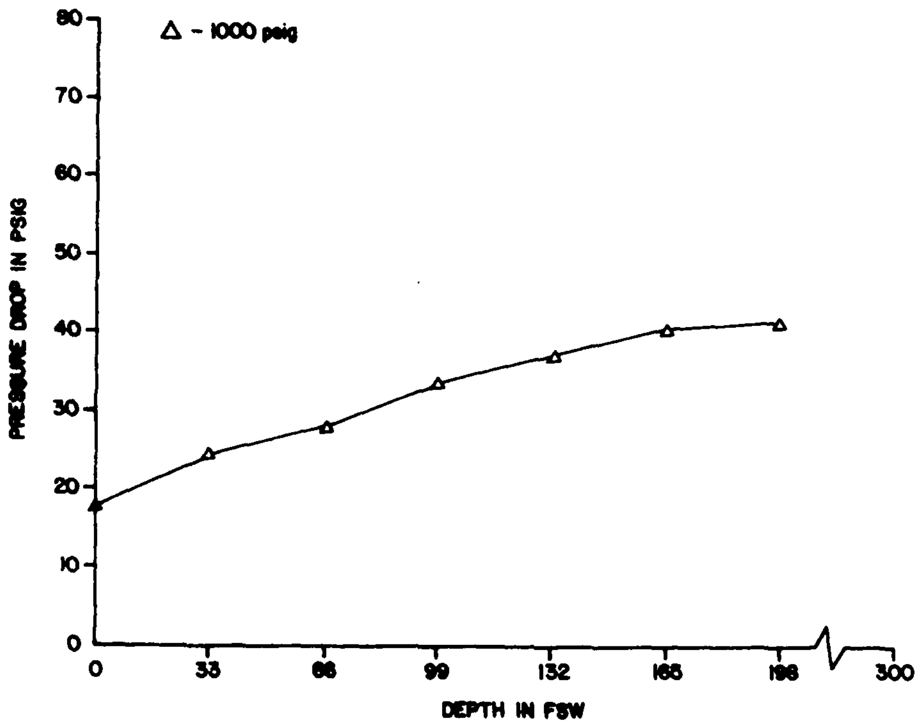

Figure 12A-8. Tekna T-2100
First stage pressure drop vs. depth at 40 RMV

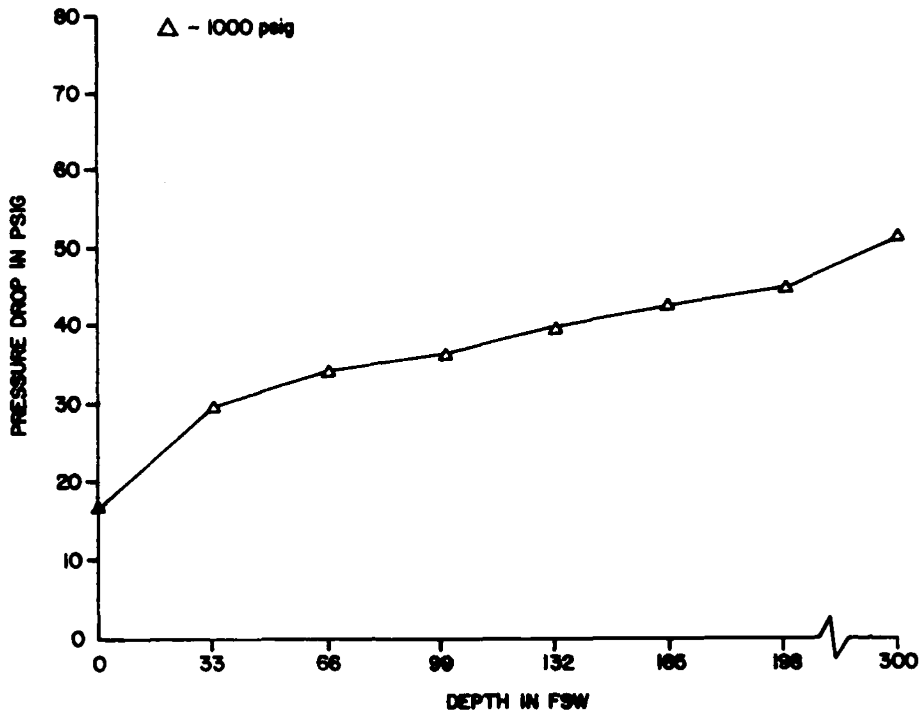

Figure 12A-9. Tekna T-2100
First stage pressure drop vs. depth at 62.5 RMV

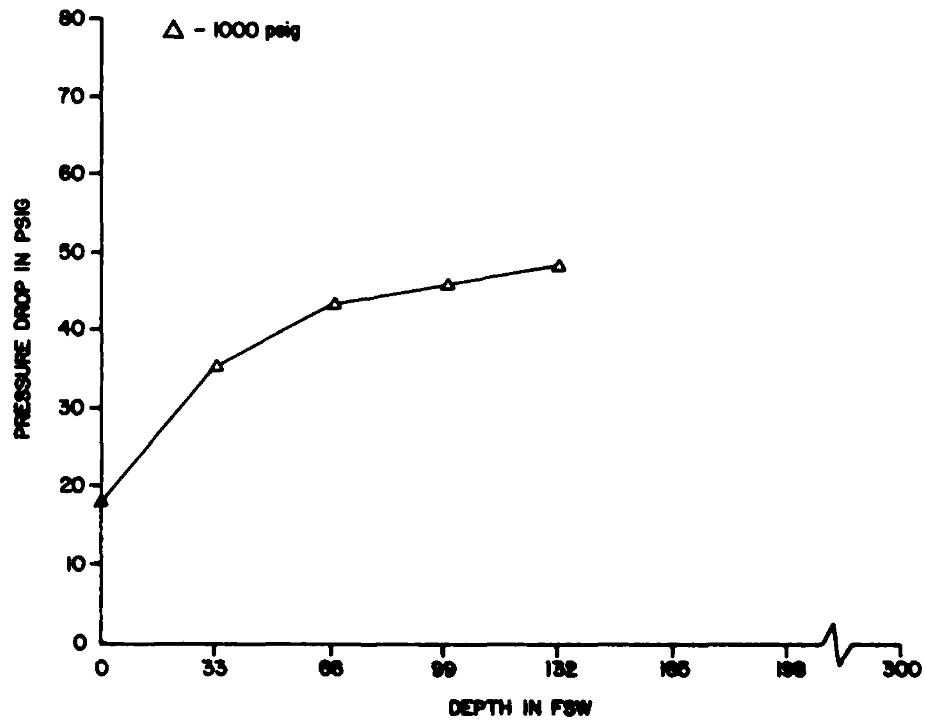

Figure 12A-10. Tekna T-2100
First stage pressure drop vs. depth at 75 RMV

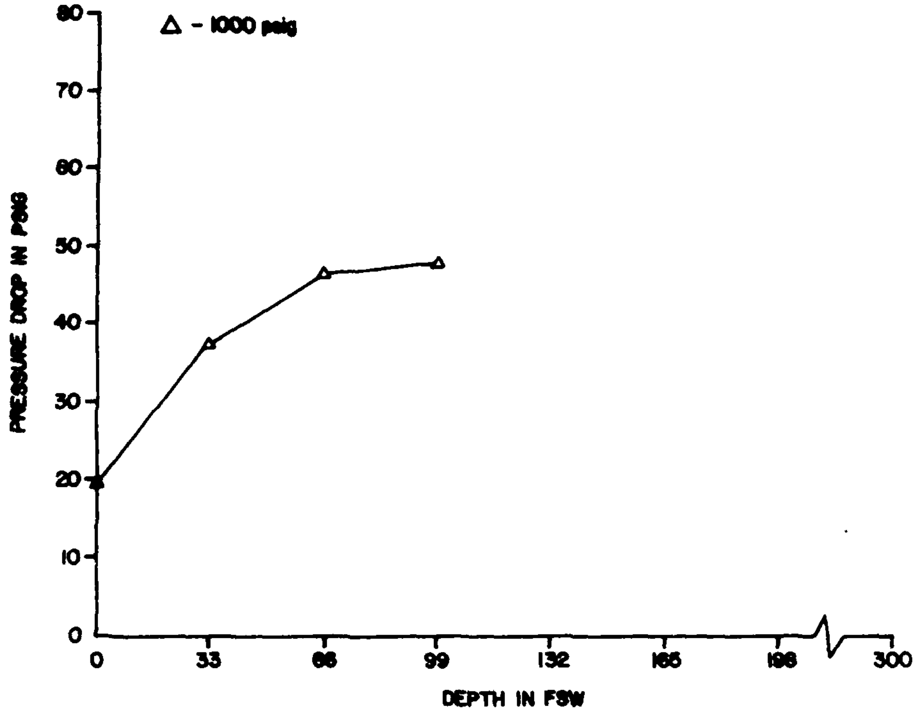

Figure 12A-11. Tekna T-2100
First stage pressure drop vs. depth at 90 RMV

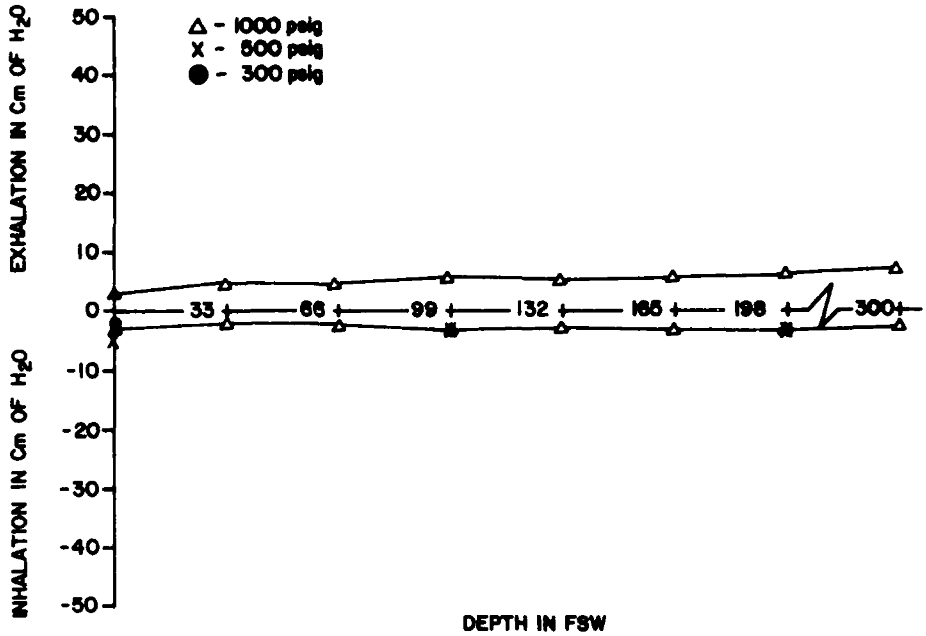

Figure 12B-1. Tekna T-2100B
Breathing resistance vs. depth at 22.5 RMV

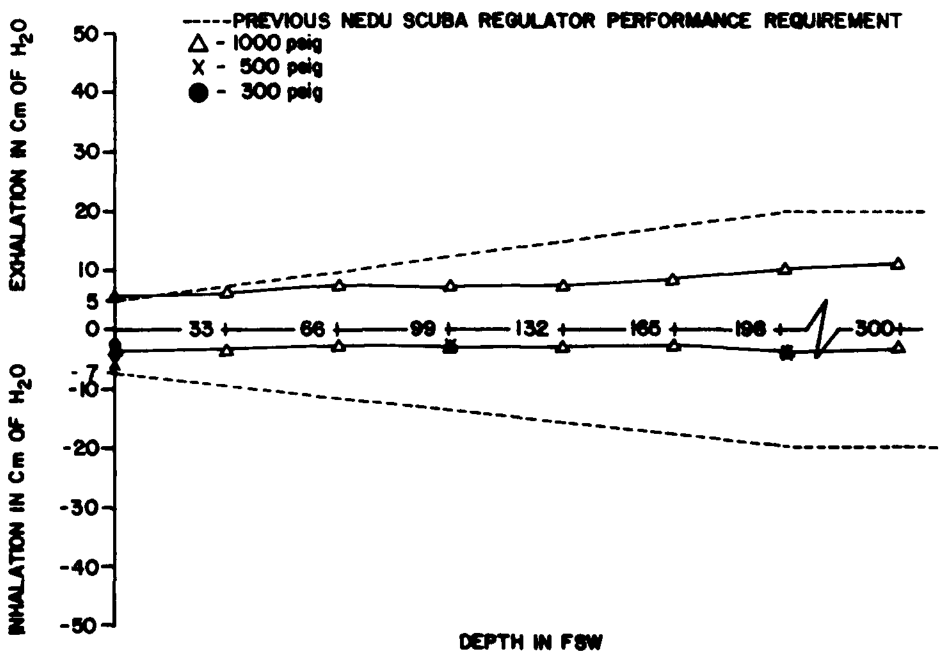

Figure 12B-2. Tekna T-2100B
Breathing resistance vs. depth at 40 RMV

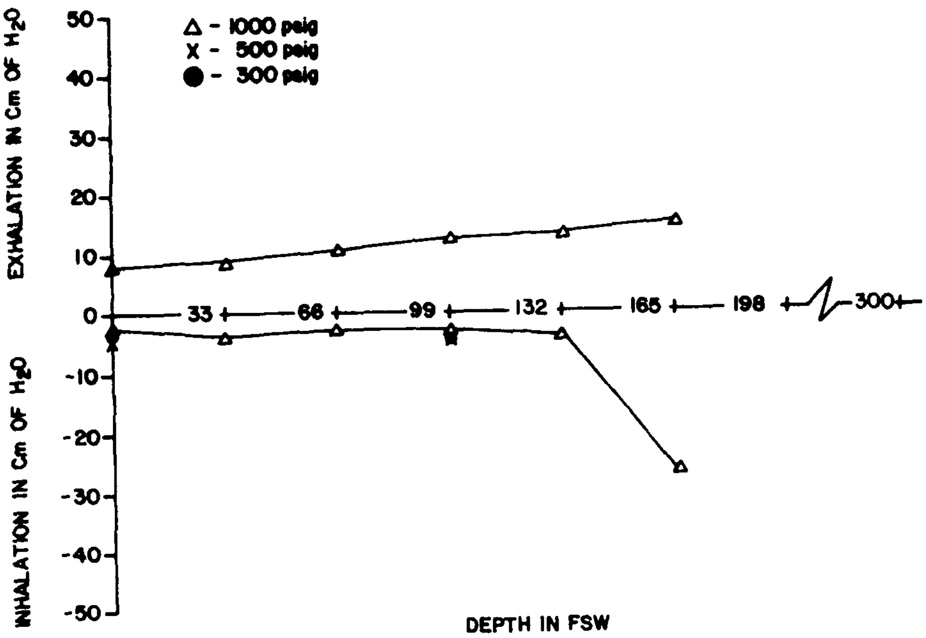

Figure 12B-3. Tekna T-2100B
Breathing resistance vs. depth at 62.5 RMV

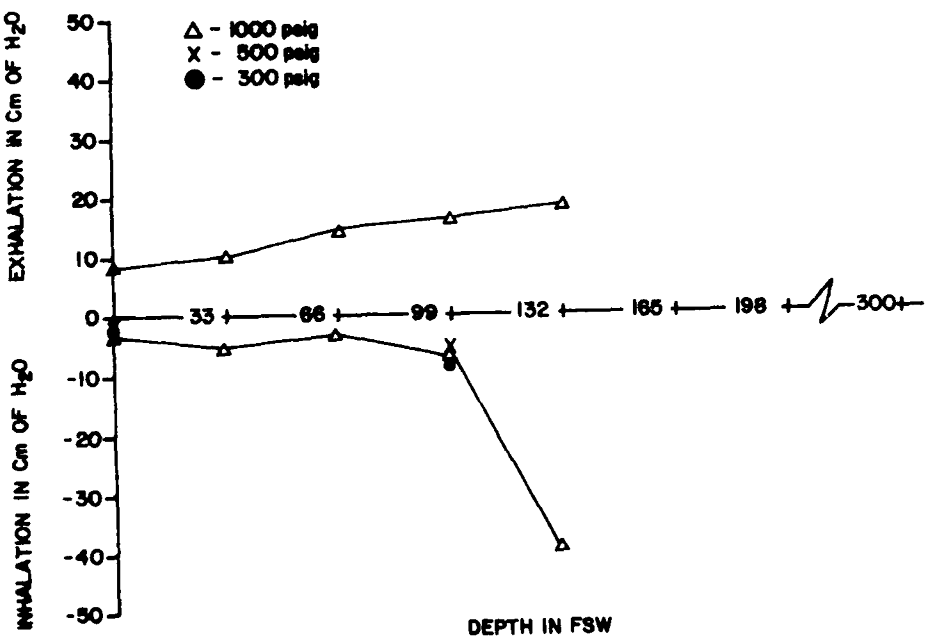

Figure 12B-4. Tekna T-2100B
Breathing resistance vs. depth at 75 RMV

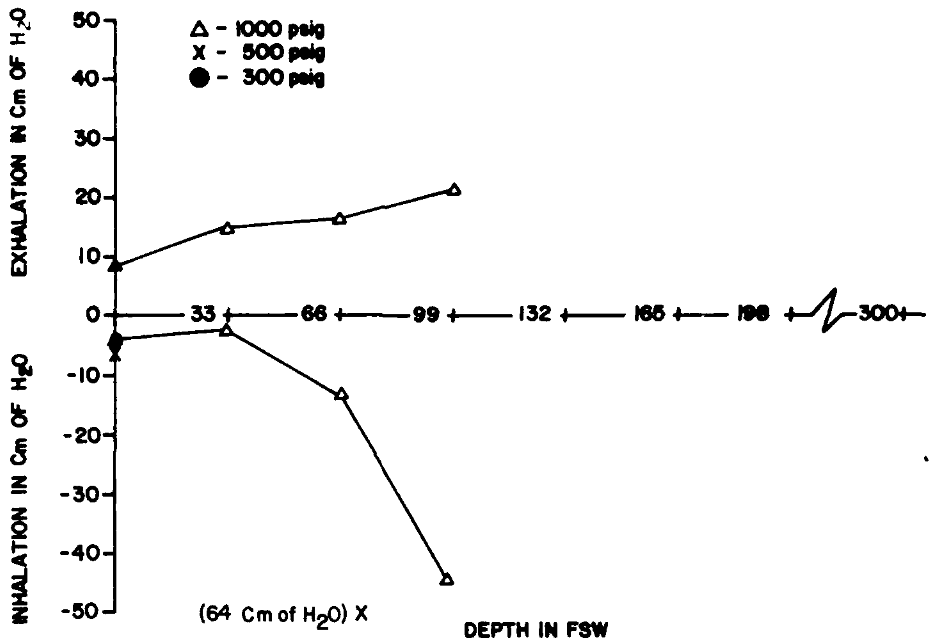

Figure 12B-5. Tekna T-2100B
Breathing resistance vs. depth at 90 RMV

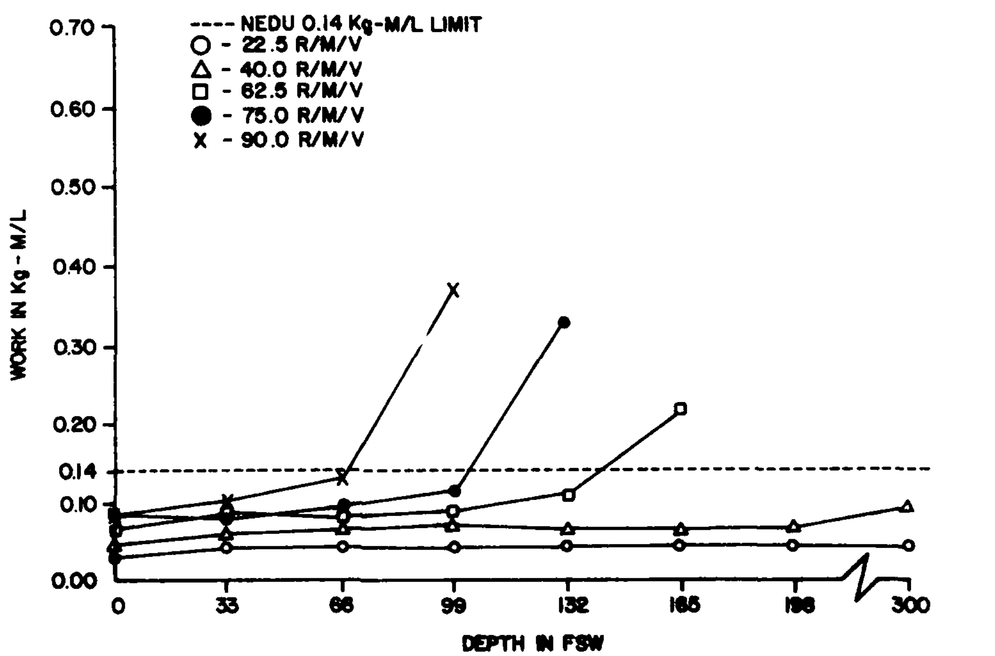

Figure 12B-6. Tekna T-2100B
Breathing work vs. depth at 1000 psig supply pressure

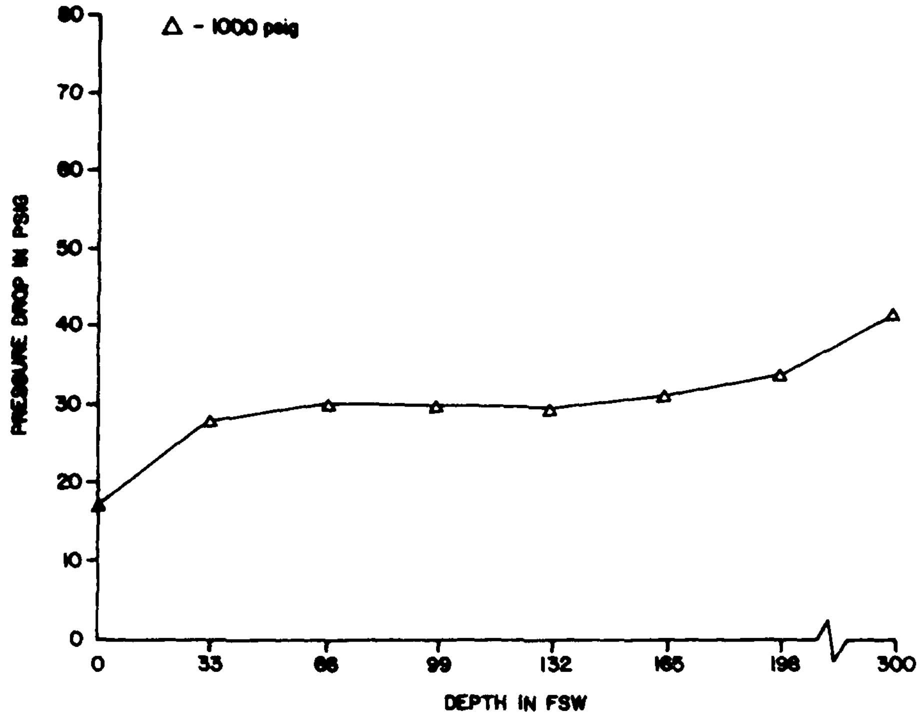

Figure 12B-7. Tekna T-2100B
First stage pressure drop vs. depth at 22.5 RMV

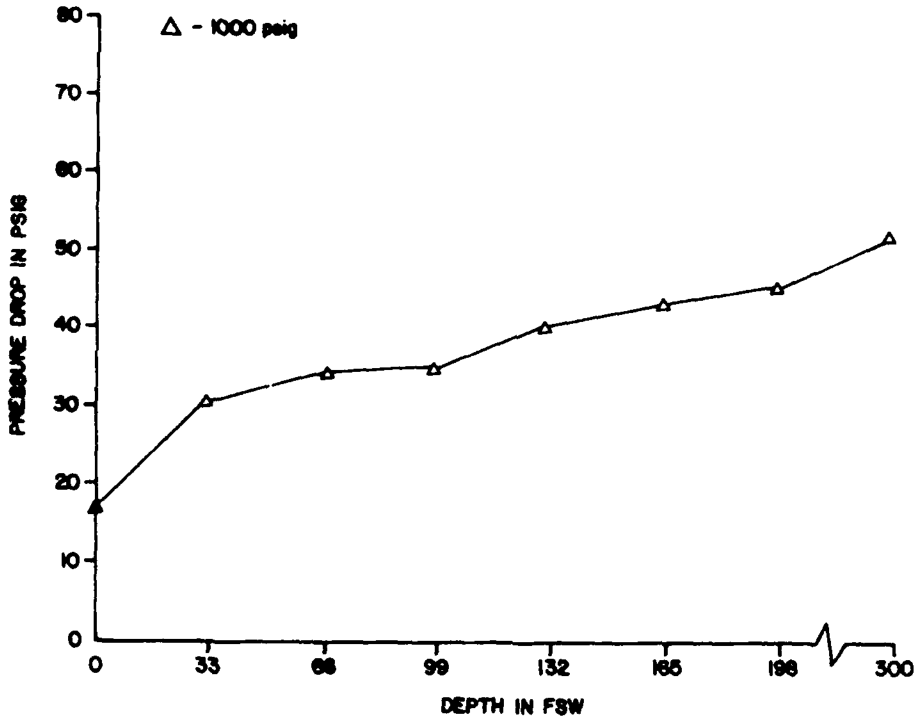

Figure 12B-8. Tekna T-2100B
First stage pressure drop vs. depth at 40 RMV

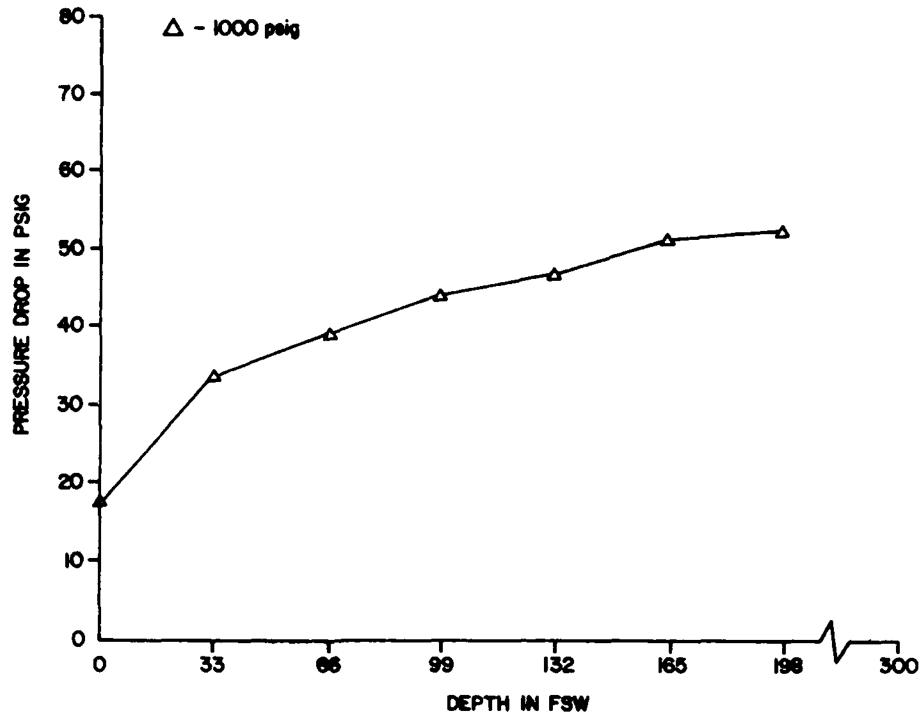

Figure 12B-9. Tekna T-2100B
First stage pressure drop vs. depth at 62.5 RMV

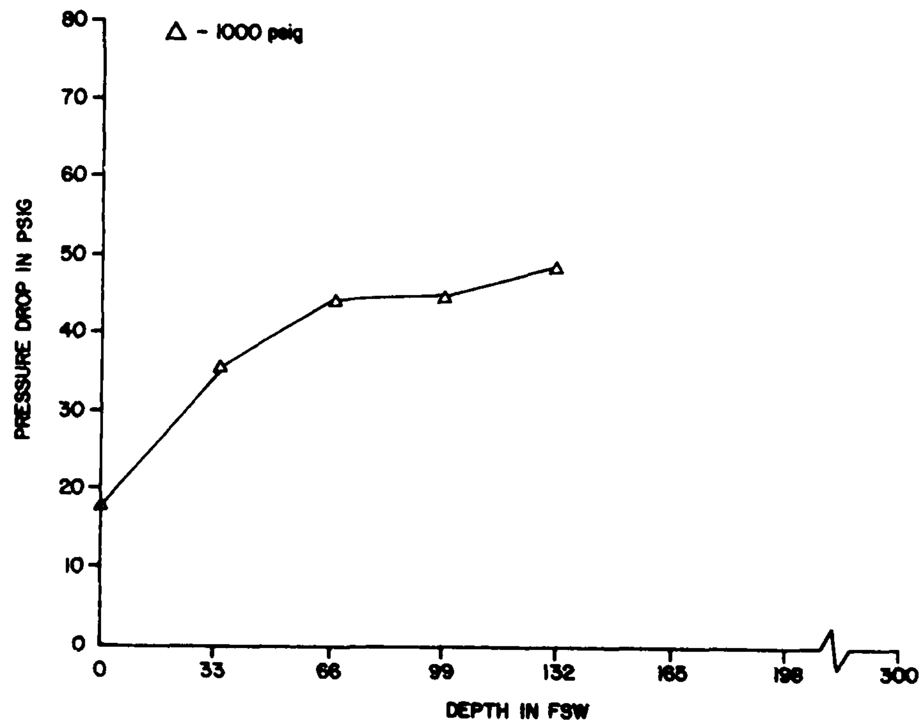

Figure 12B-10. Tekna T-2100B
First stage pressure drop vs. depth at 75 RMV

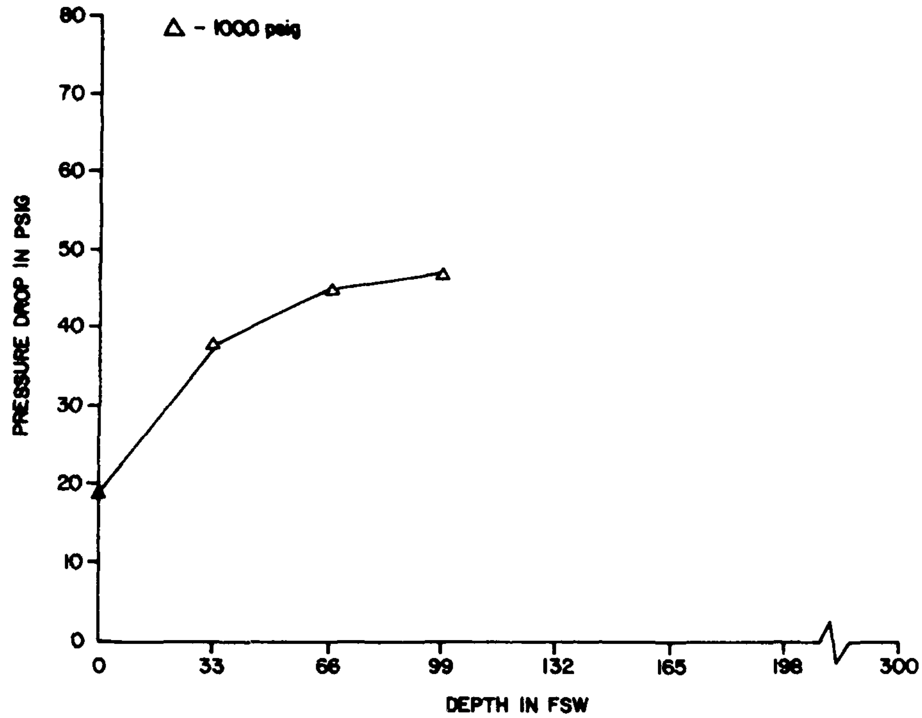

Figure 12B-11. Tekna T-2100B
First stage pressure drop vs. depth at 90 RMV

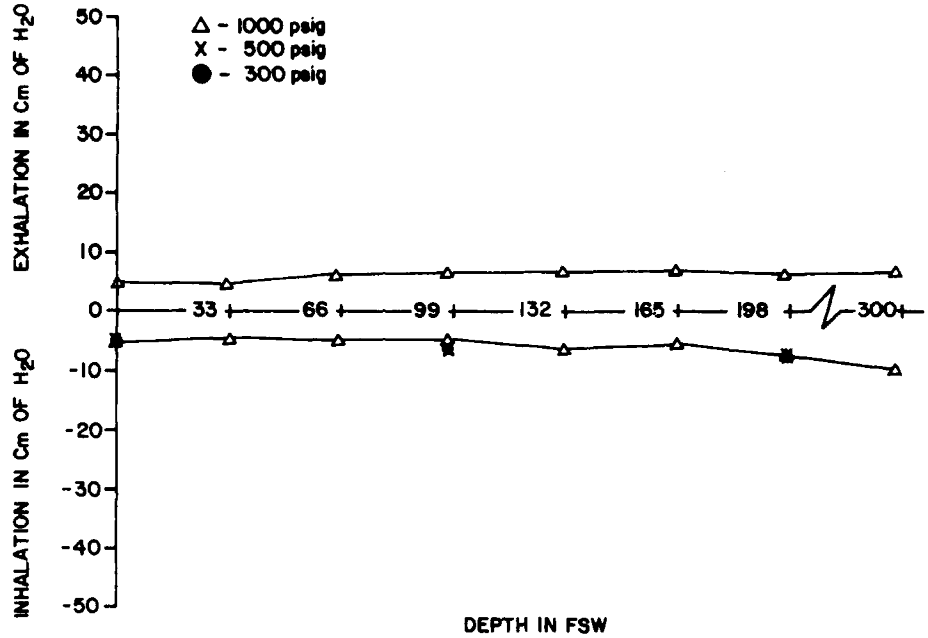

Figure 13A-1. U. S. Divers Aquarius
Breathing resistance vs. depth at 22.5 RMV

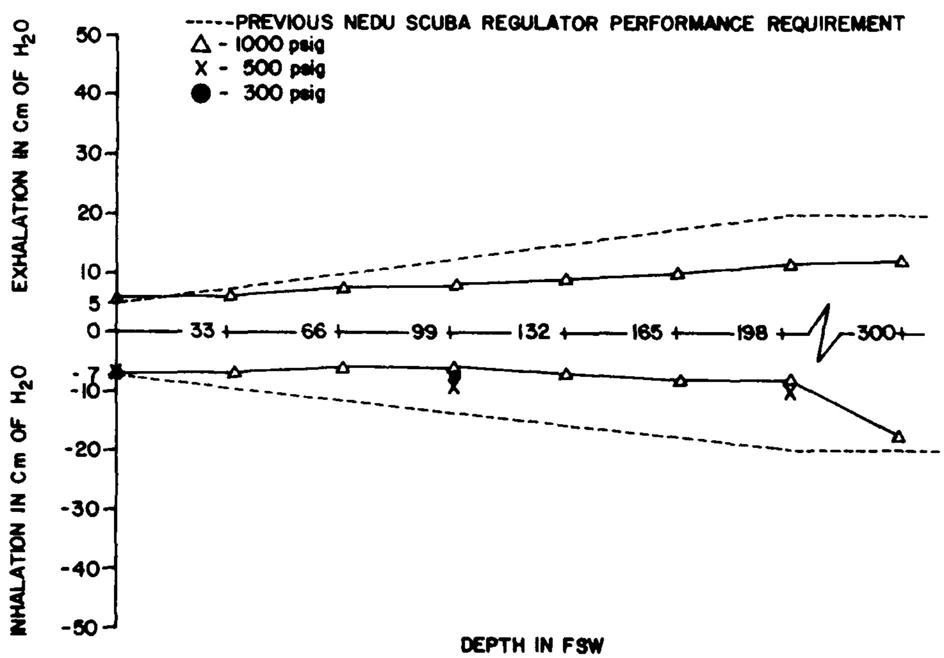

Figure 13A-2. U. S. Divers Aquarius
Breathing resistance vs. depth at 40 RMV

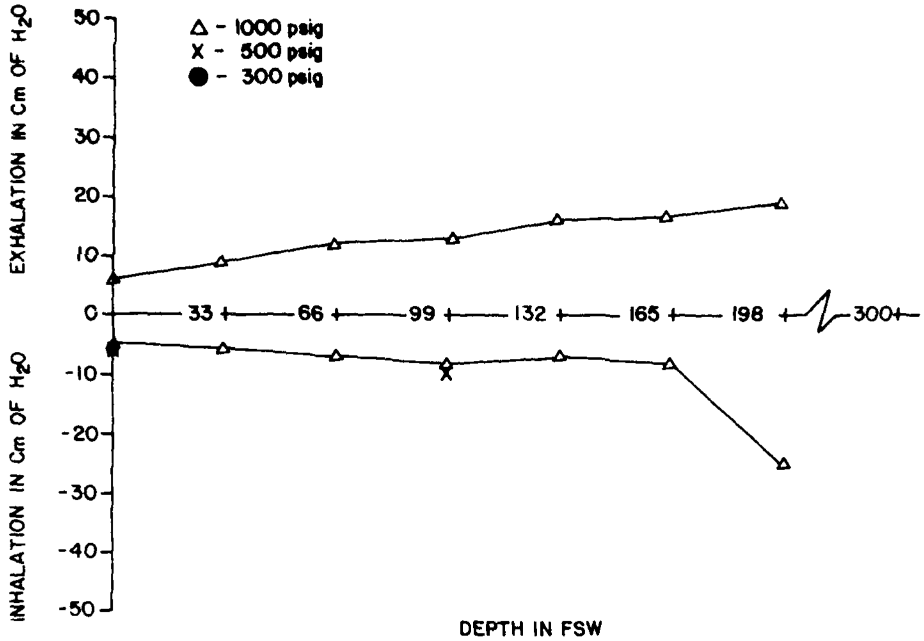

Figure 13A-3. U. S. Divers Aquarius
Breathing resistance vs. depth at 62.5 RMV

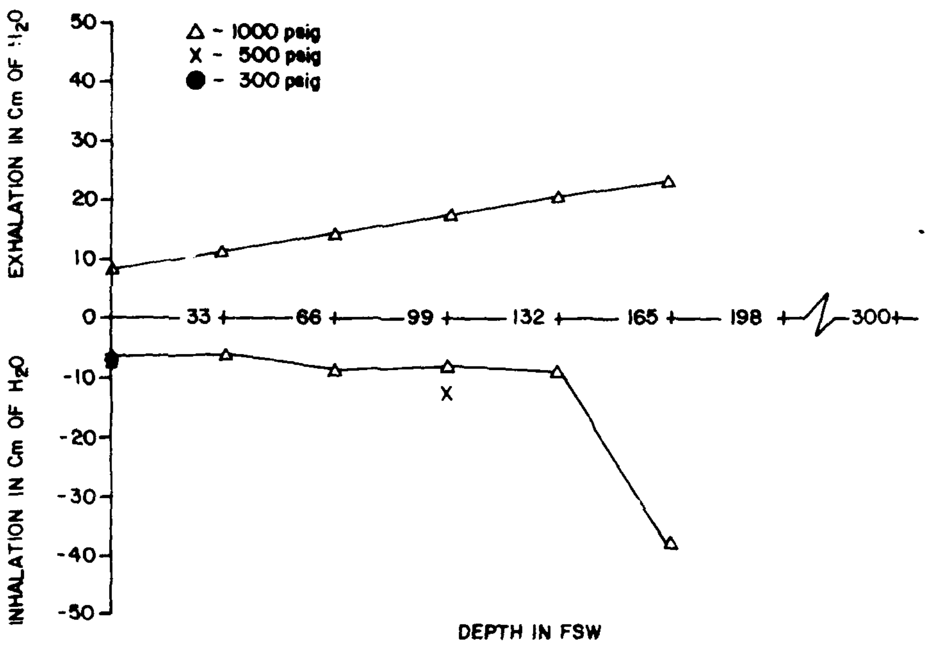

Figure 13A-4. U. S. Divers Aquarius
Breathing resistance vs. depth at 75 RMV

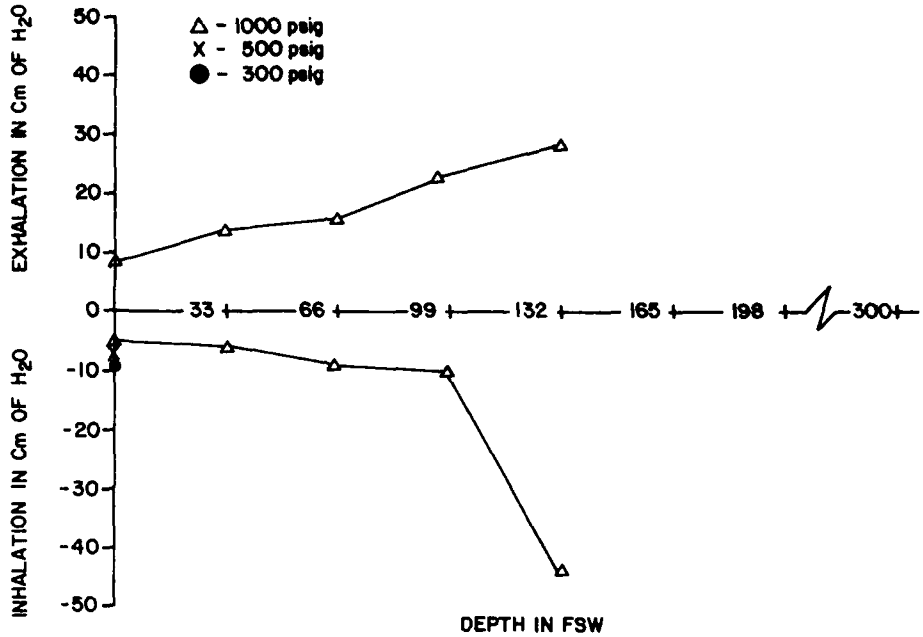

Figure 13A-5. U. S. Divers Aquarius
Breathing resistance vs. depth at 90 RMV

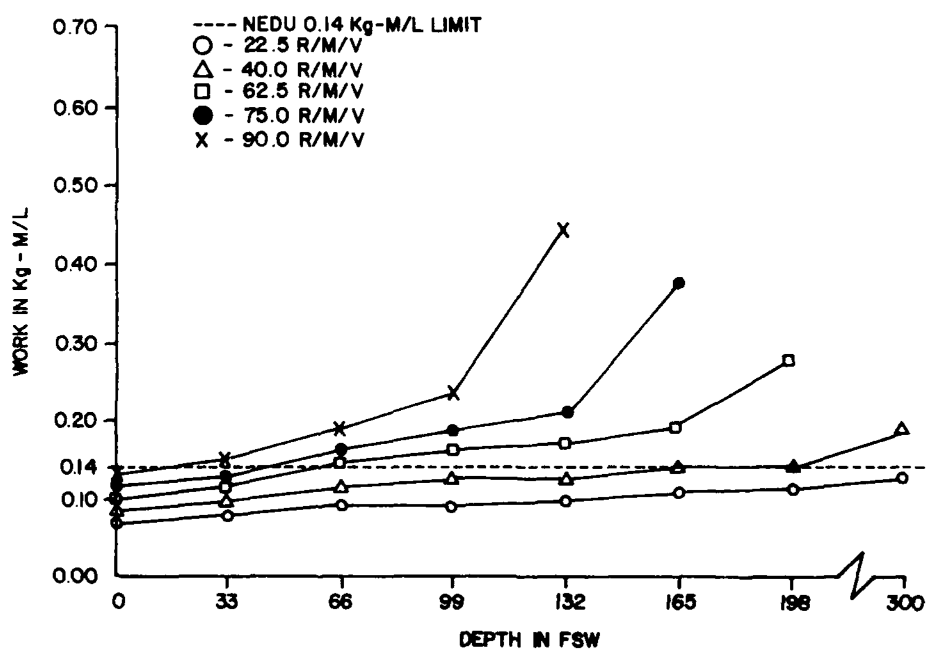

Figure 13A-6. U. S. Divers Aquarius
Breathing work vs. depth at 1000 psig supply pressure

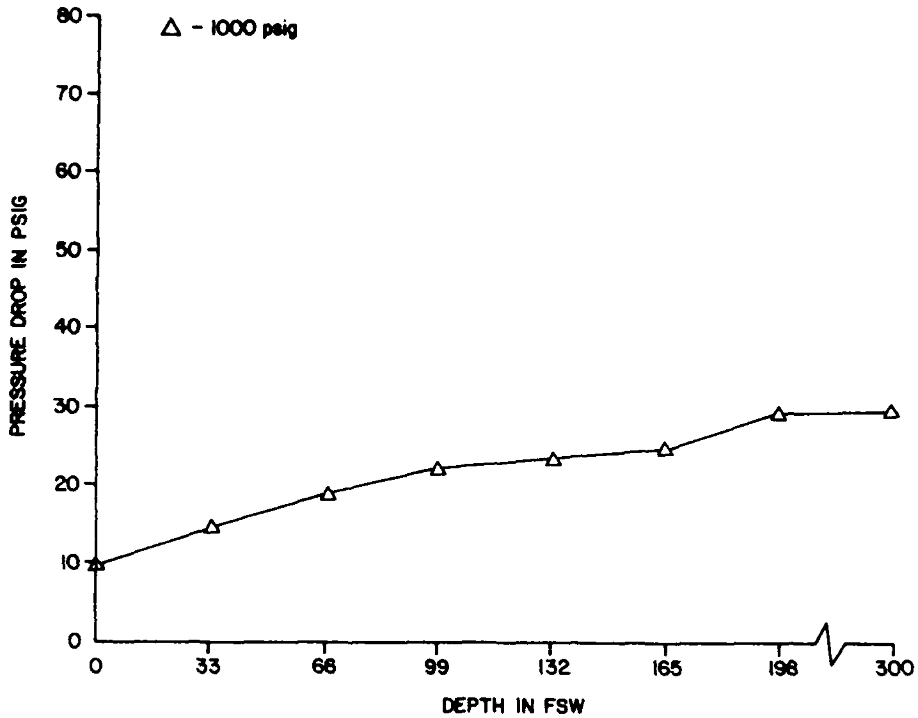

Figure 13A-7. U. S. Divers Aquarius
First stage pressure drop vs. depth at 22.5 RMV

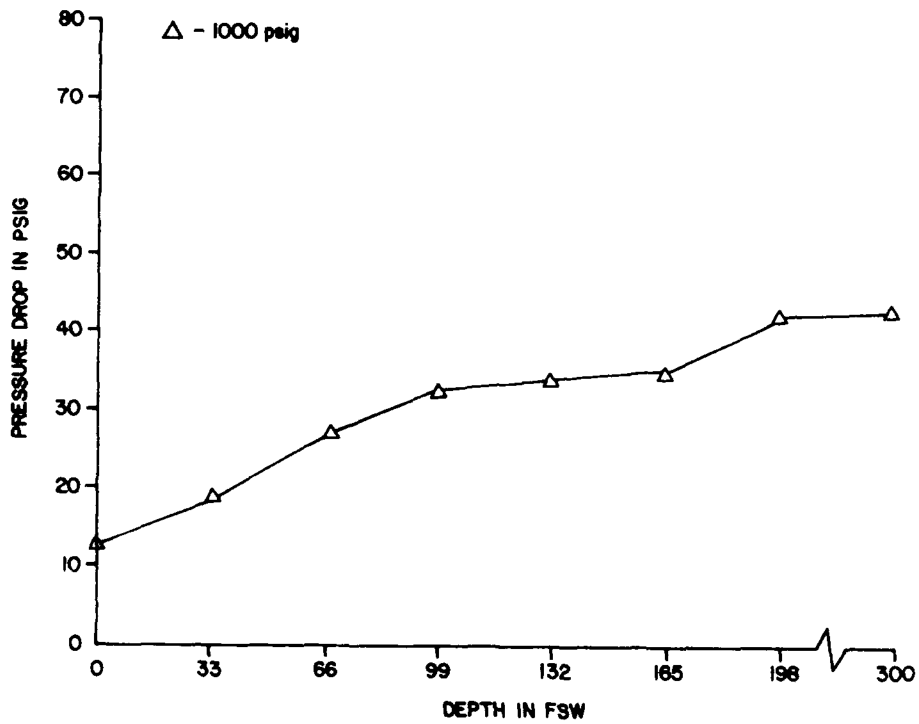

Figure 13A-8. U. S. Divers Aquarius
First stage pressure drop vs. depth at 40 RMV

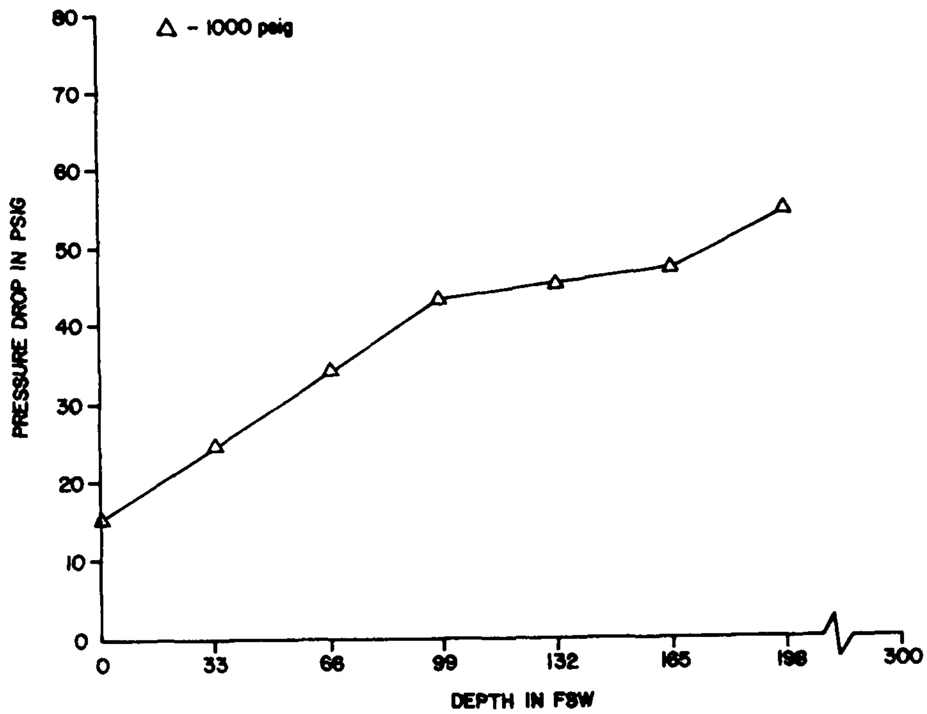

Figure 13A-9. U. S. Divers Aquarius
First stage pressure drop vs. depth at 62.5 RMV

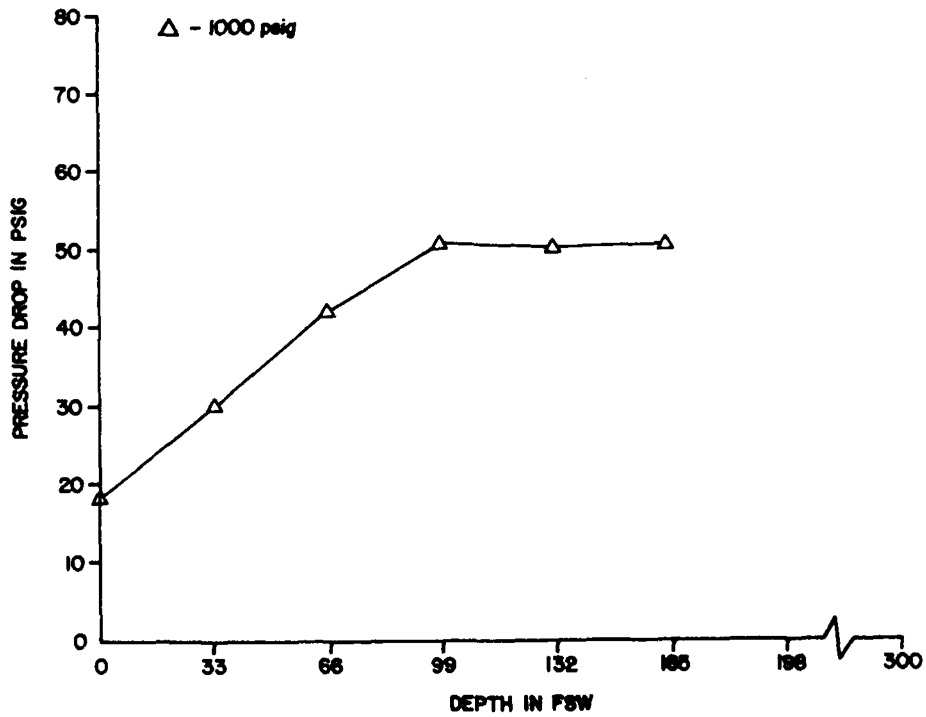

Figure 13A-10. U. S. Divers Aquarius
First stage pressure drop vs. depth at 75 RMV

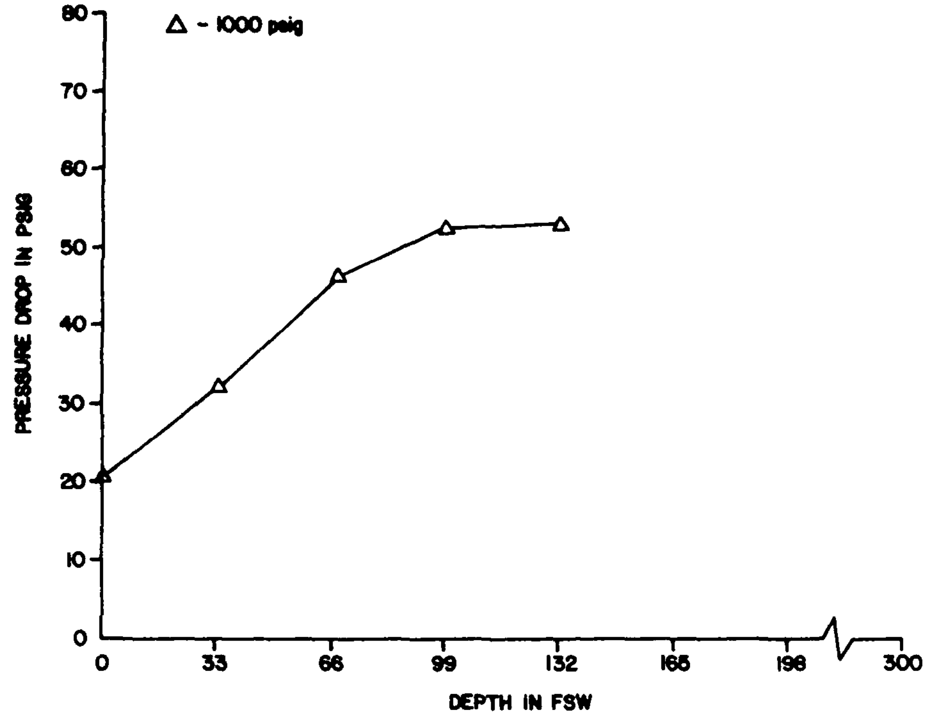

Figure 13A-11. U. S. Divers Aquarius
First stage pressure drop vs. depth at 90 RMV

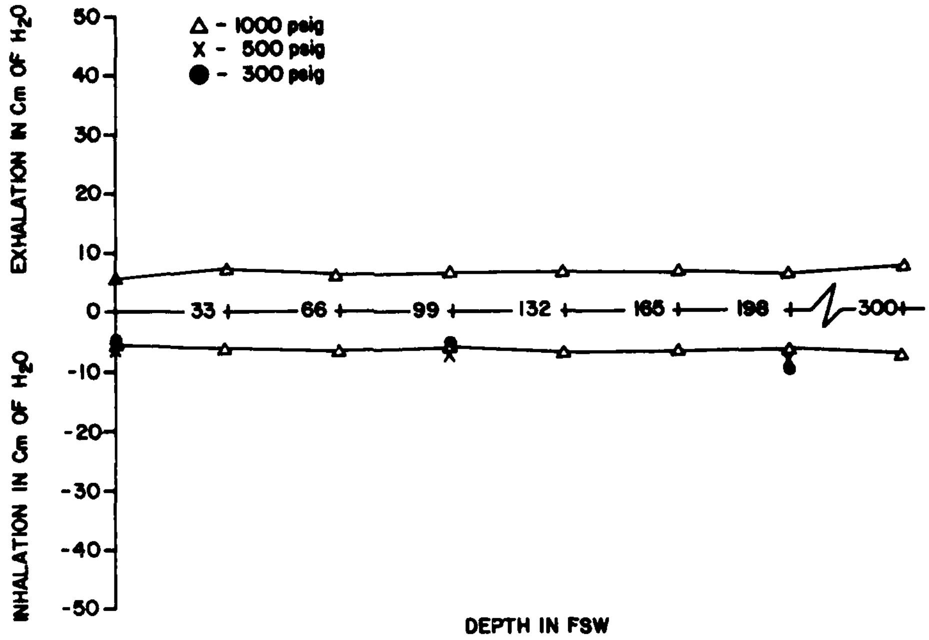

Figure 13B-1. U. S. Divers Calypso VI
Breathing resistance vs. depth at 22.5 RMV

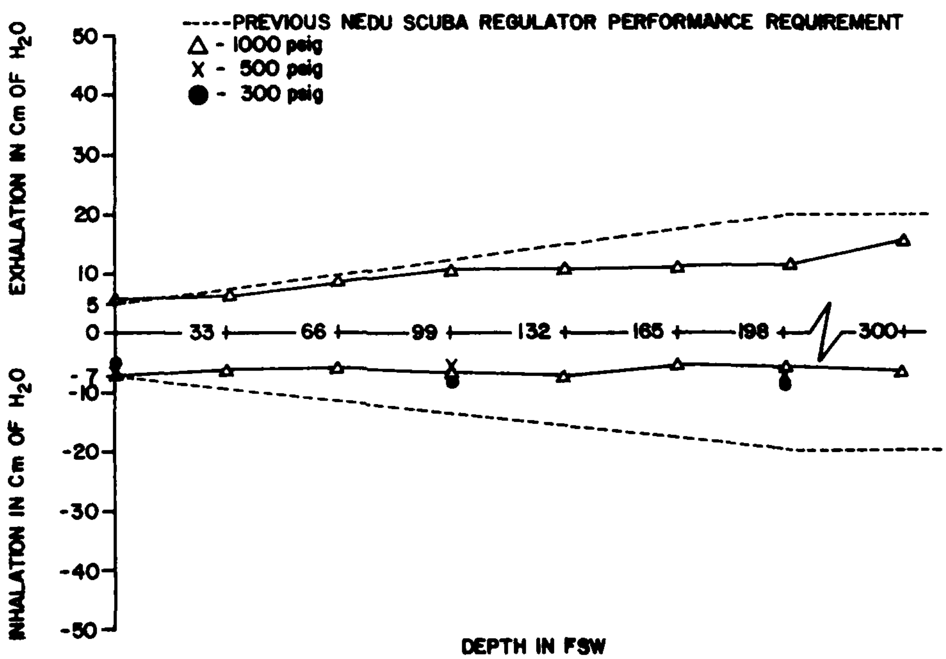

Figure 13B-2. U. S. Divers Calypso VI
Breathing resistance vs. depth at 40 RMV

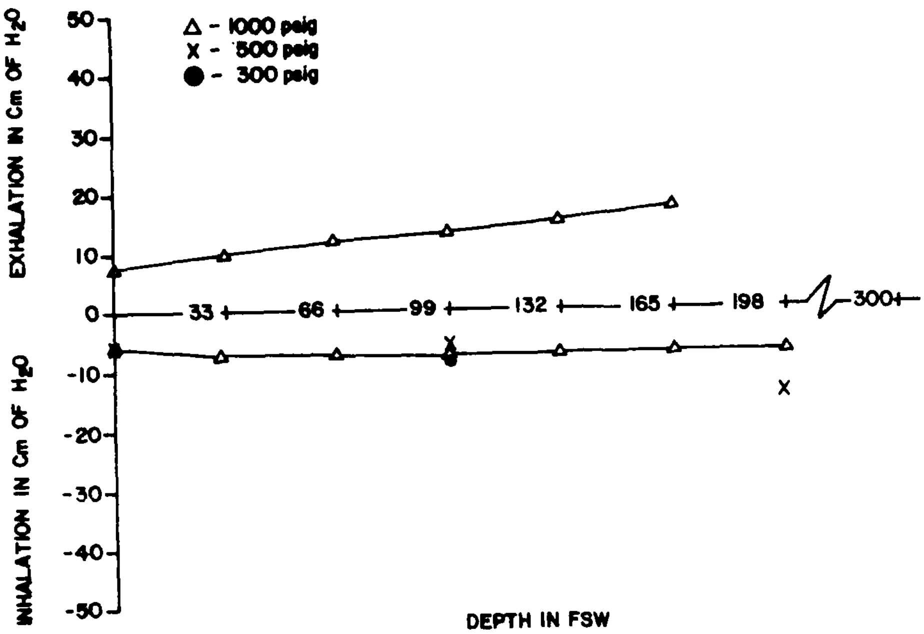

Figure 13B-3. U. S. Divers Calypso VI
Breathing resistance vs. depth at 62.5 RMV

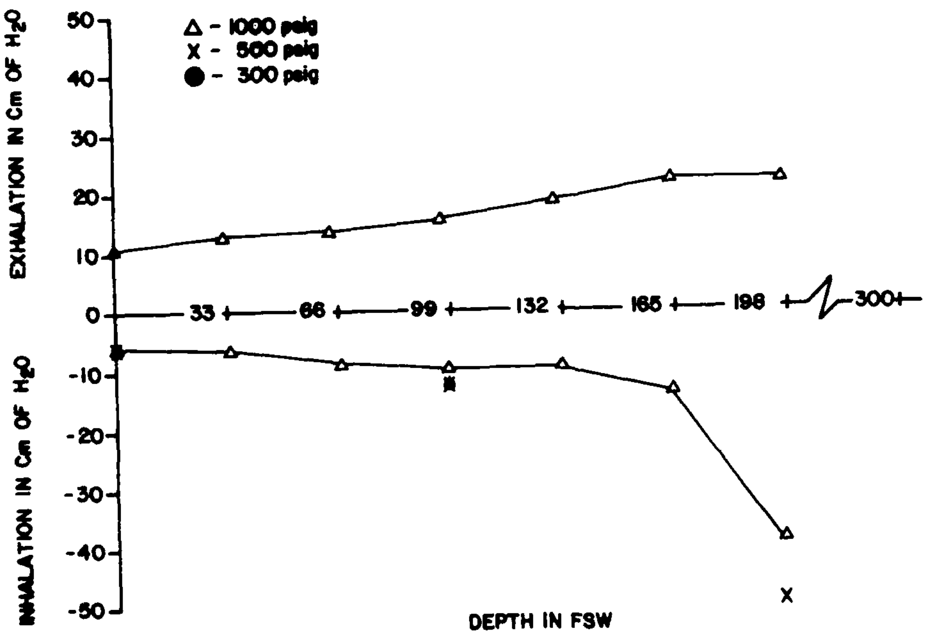

Figure 13B-4. U. S. Divers Calypso VI
Breathing resistance vs. depth at 75 RMV

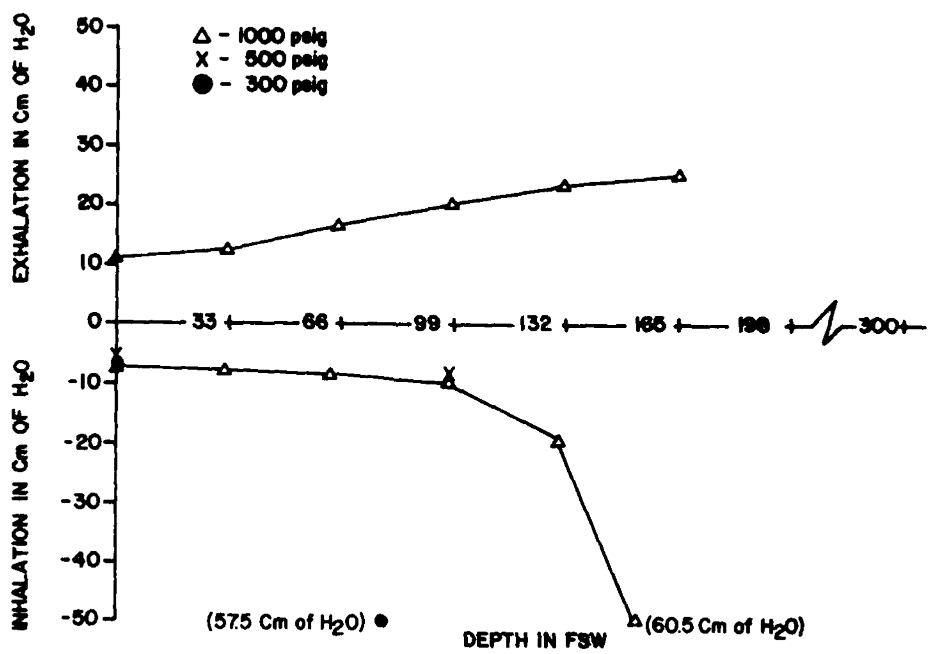

Figure 13B-5. U. S. Divers Calypso VI
Breathing resistance vs. depth at 90 RMV

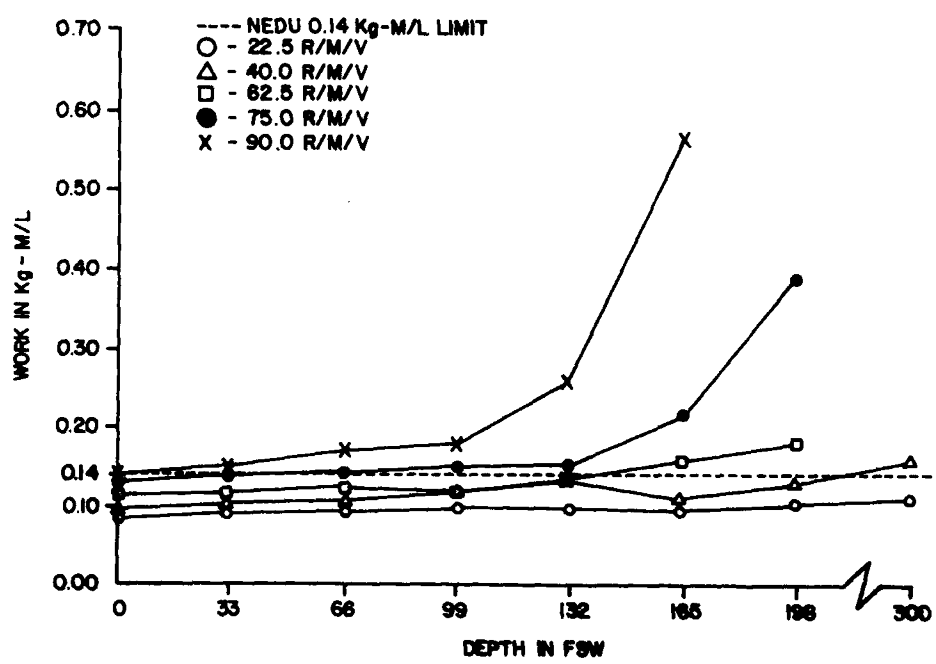

Figure 13B-6. U. S. Divers Calypso VI
Breathing work vs. depth at 1000 psig supply pressure

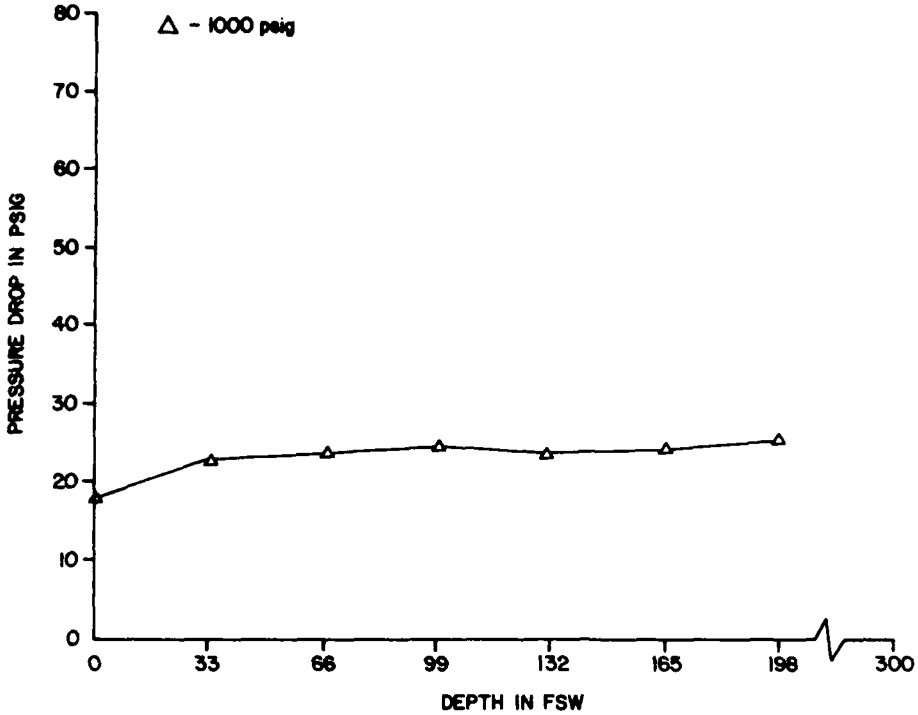

Figure 13B-7. U. S. Divers Calypso VI
First stage pressure drop vs. depth at 22.5 RMV

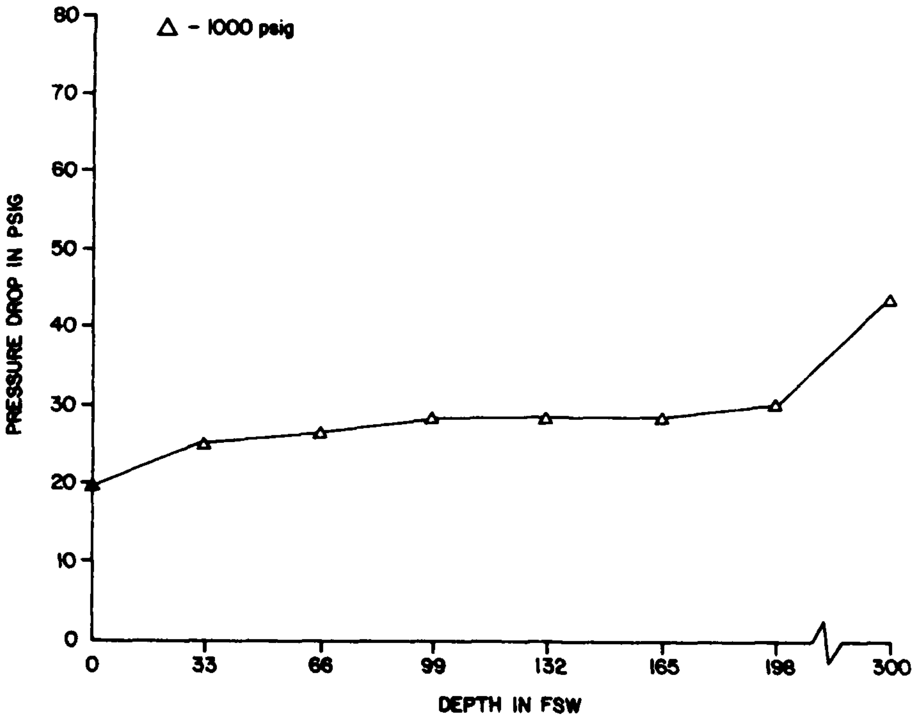

Figure 13B-8. U. S. Divers Calypso VI
First stage pressure drop vs. depth at 40 RMV

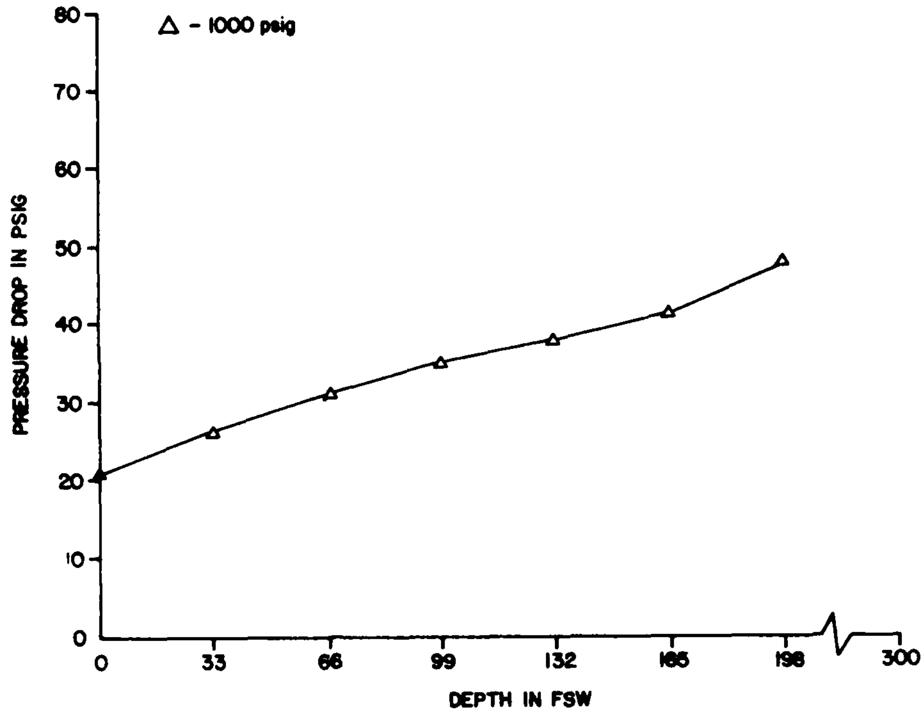

Figure 13B-9. U. S. Divers Calypso VI
First stage pressure drop vs. depth at 62.5 RMV

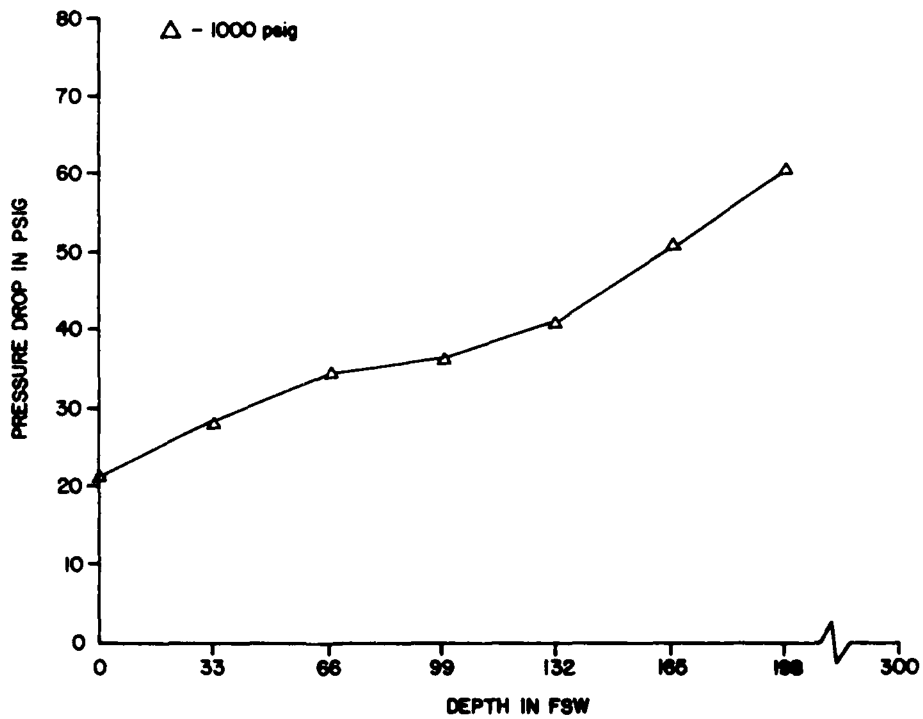

Figure 13B-10. U. S. Divers Calypso VI
First stage pressure drop vs. depth at 75 RMV

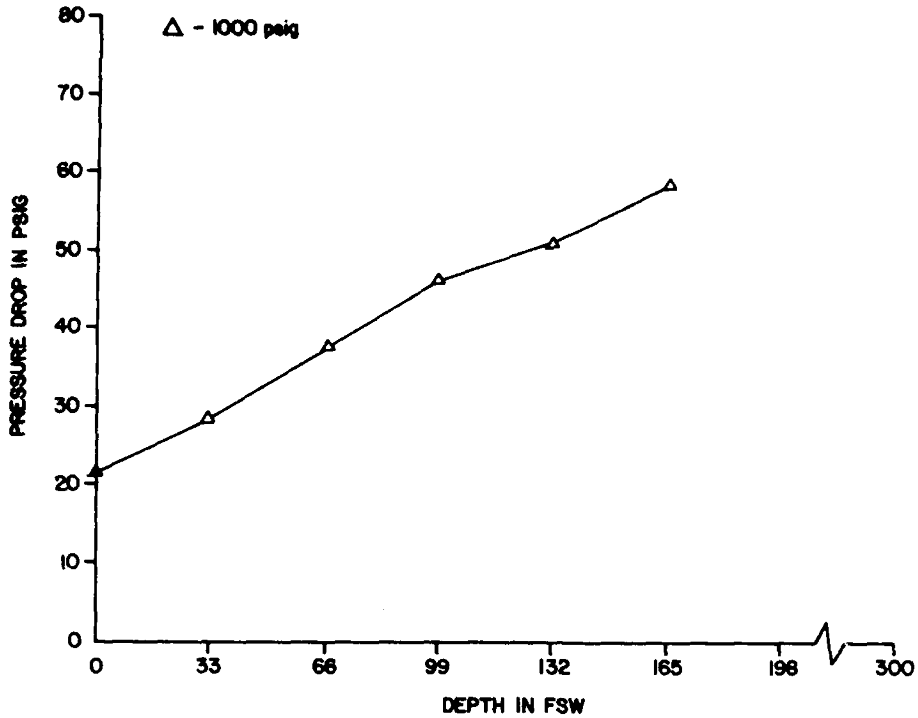

Figure 13B-11. U. S. Divers Calypso VI
First stage pressure drop vs. depth at 90 RMV

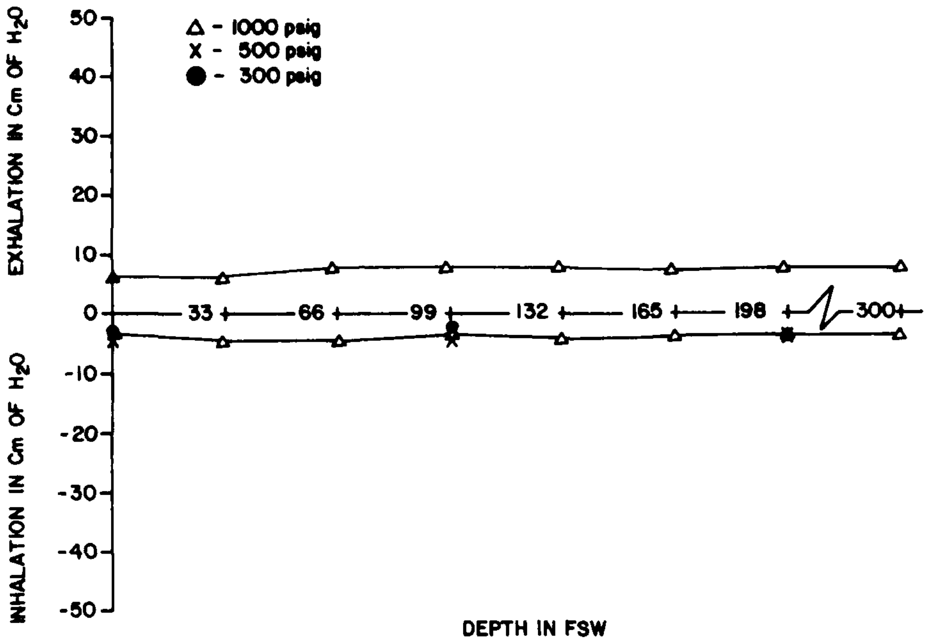

Figure 13C-1. U. S. Divers Conshelf XIV
Breathing resistance vs. depth at 22.5 RMV

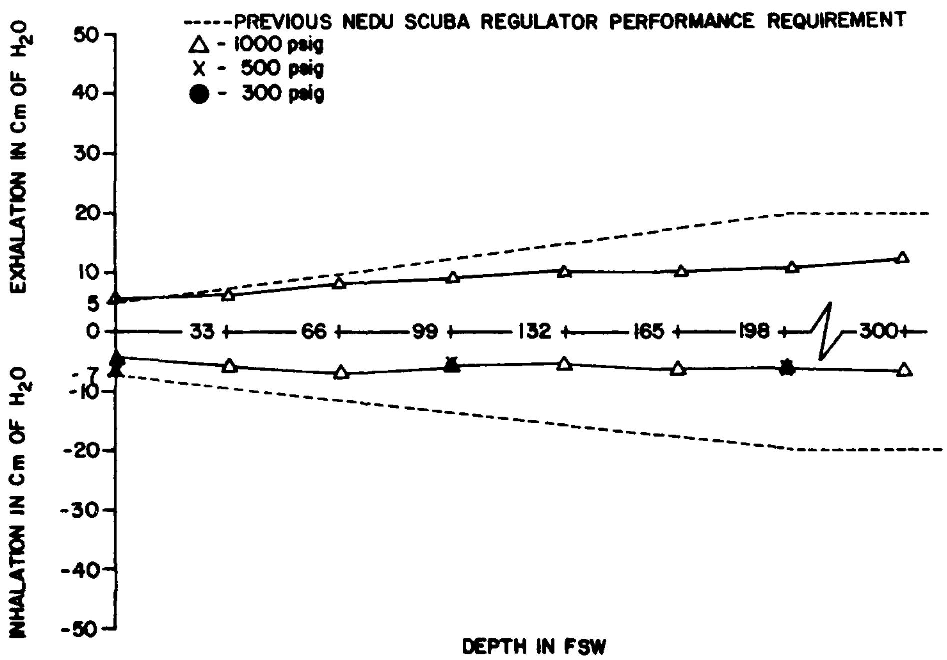

Figure 13C-2. U. S. Divers Conshelf XIV
Breathing resistance vs. depth at 40 RMV

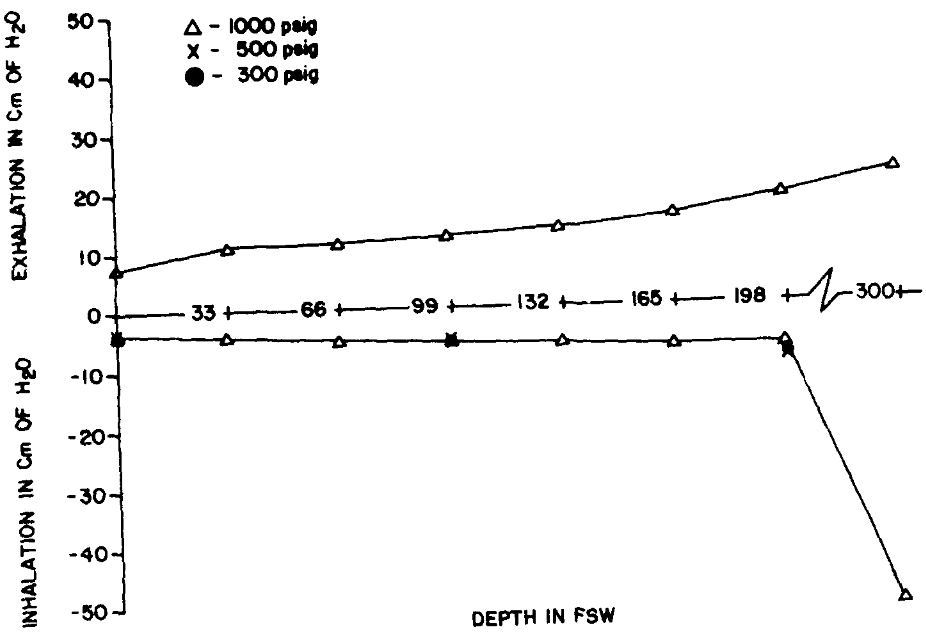

Figure 13C-3. U. S. Divers Conshelf XIV
Breathing resistance vs. depth at 62.5 RMV

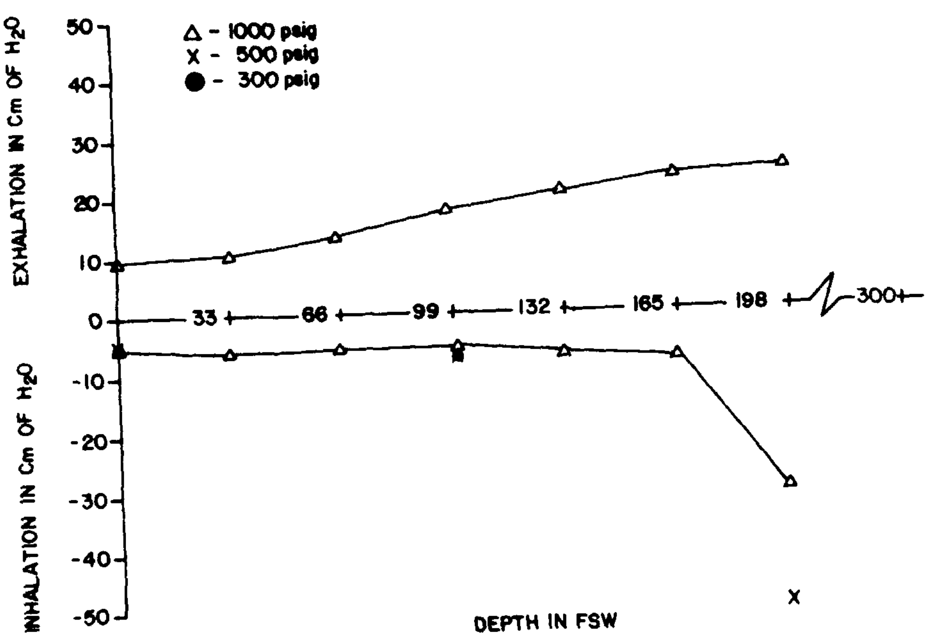

Figure 13C-4. U. S. Divers Conshelf XIV
Breathing resistance vs. depth at 75 RMV

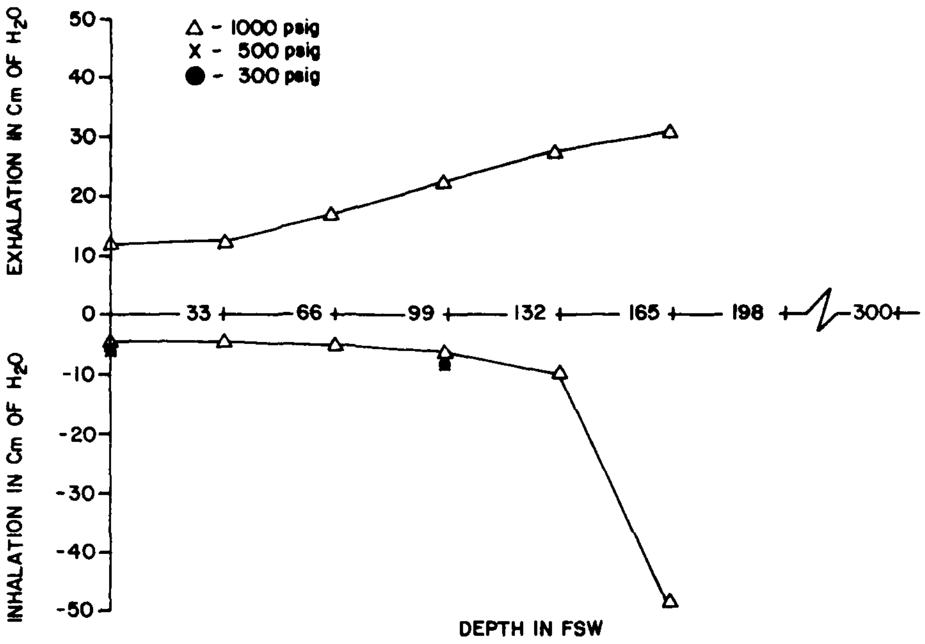

Figure 13C-5. U. S. Divers Conshelf XIV
Breathing resistance vs. depth at 90 RMV

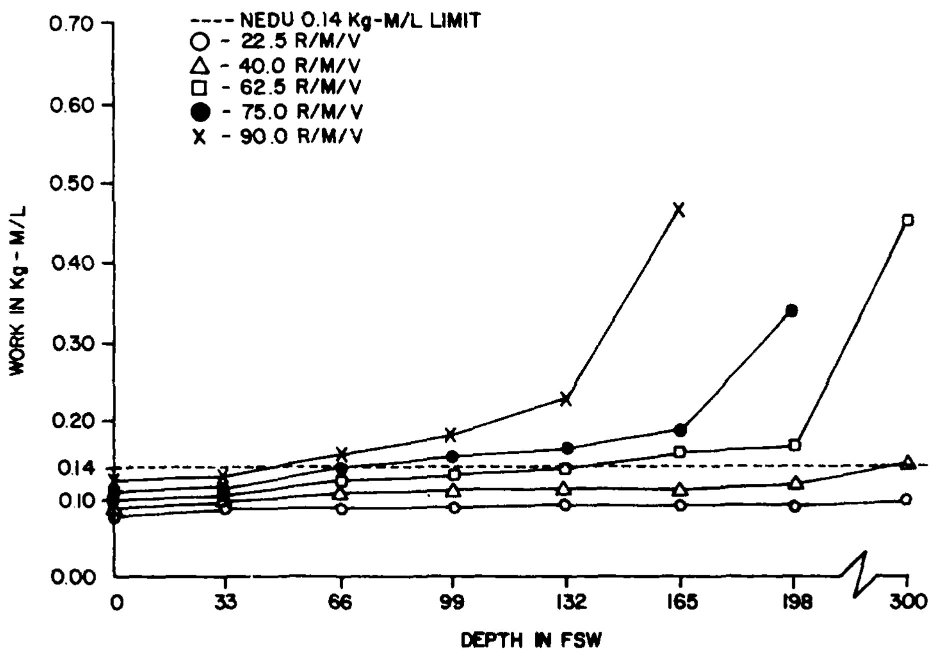

Figure 13C-6. U. S. Divers Conshelf XIV
Breathing work vs. depth at 1000 psig supply pressure

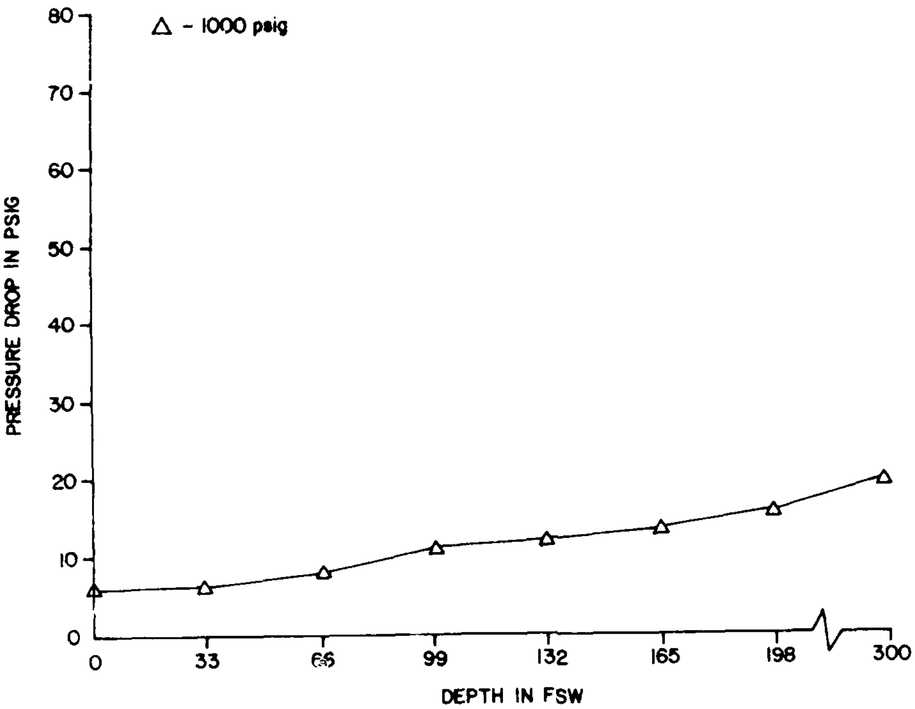

Figure 13C-7. U. S. Divers Conshelf XIV
First stage pressure drop vs. depth at 22.5 RMV

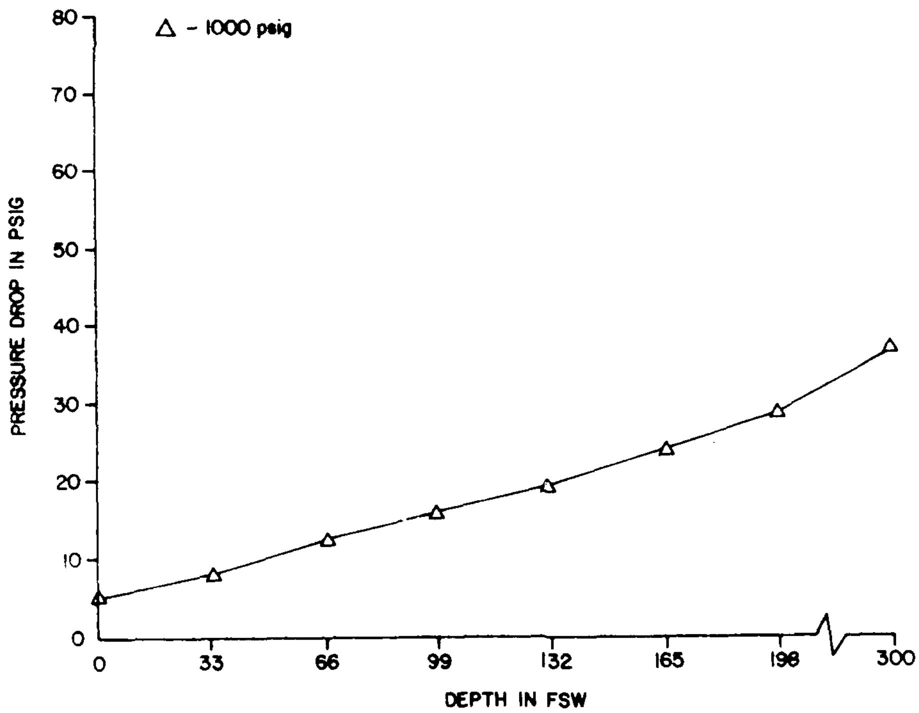

Figure 13C-8. U. S. Divers Conshelf XIV
First stage pressure drop vs. depth at 40 RMV

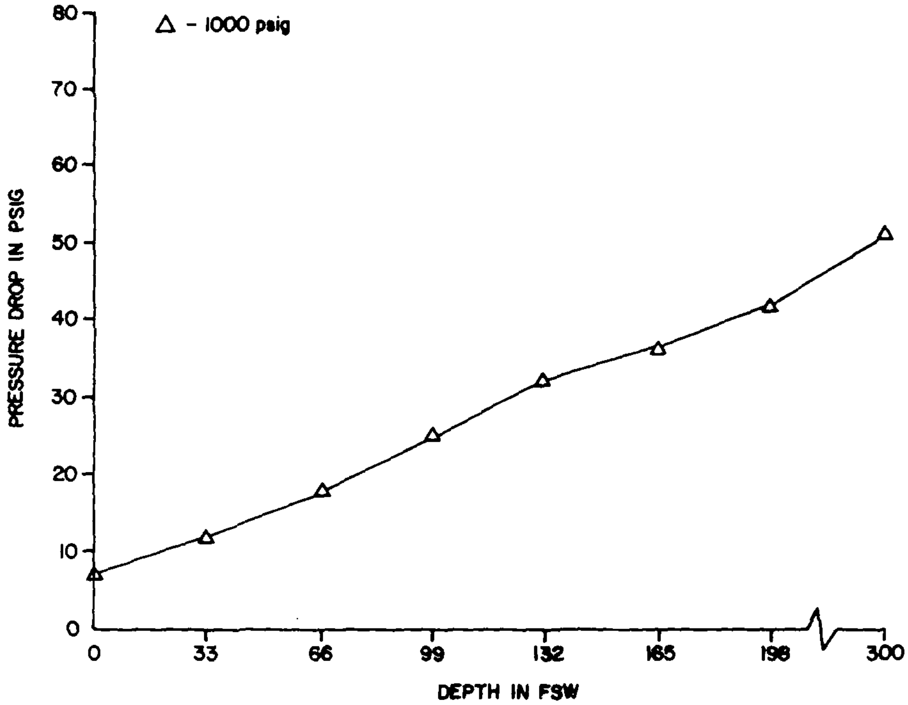

Figure 13C-9. U. S. Divers Conshelf XIV
First stage pressure drop vs. depth at 62.5 RMV

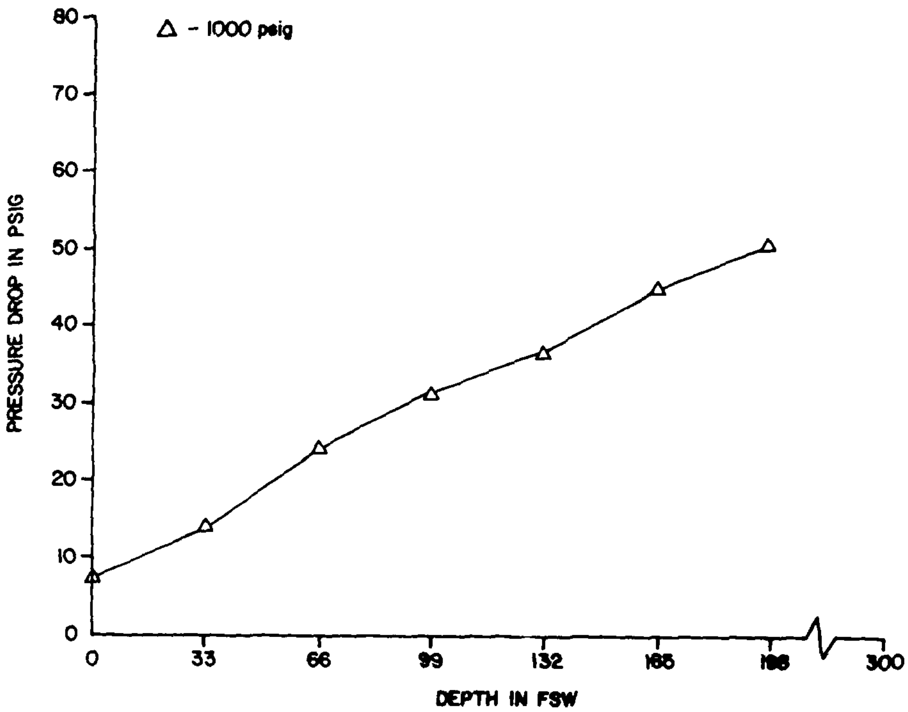

Figure 13C-10. U. S. Divers Conshelf XIV
First stage pressure drop vs. depth at 75 RMV

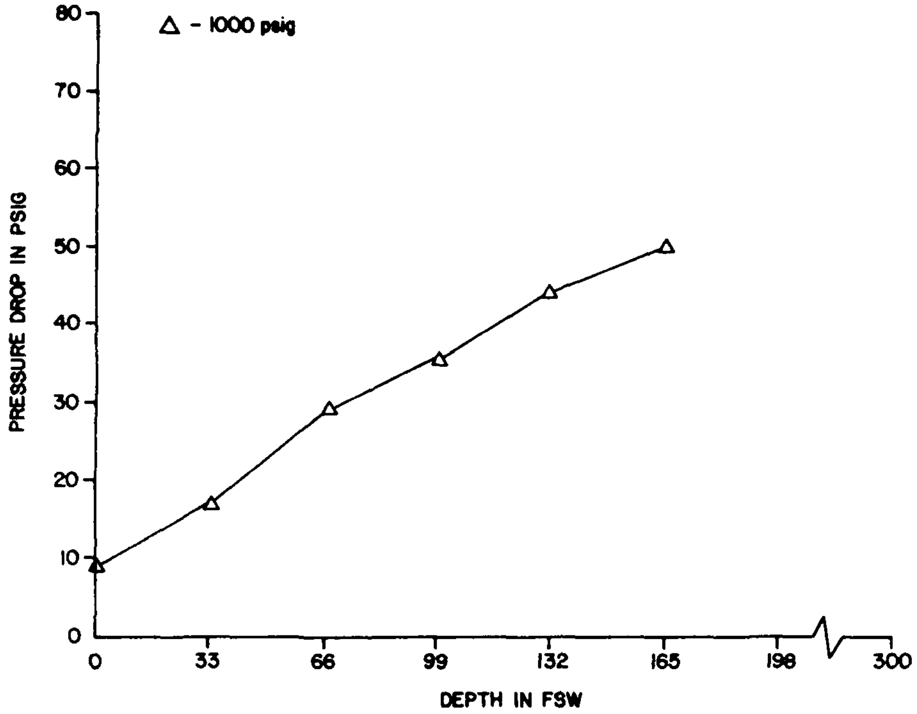

Figure 13C-11. U. S. Divers Conshelf XIV
First stage pressure drop vs. depth at 90 RMV

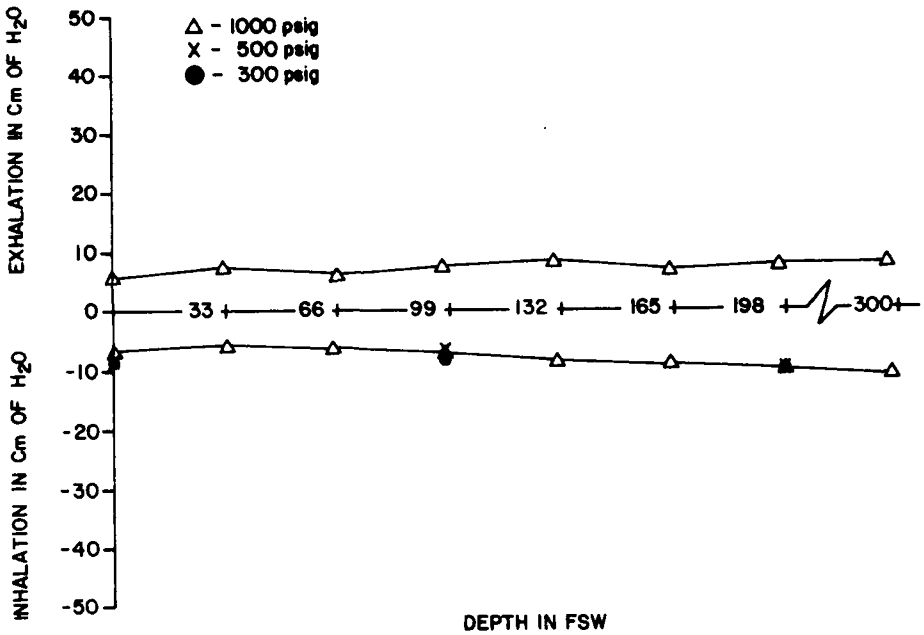

Figure 14A-1. White Stag Deep V
Breathing resistance vs. depth at 22.5 RMV

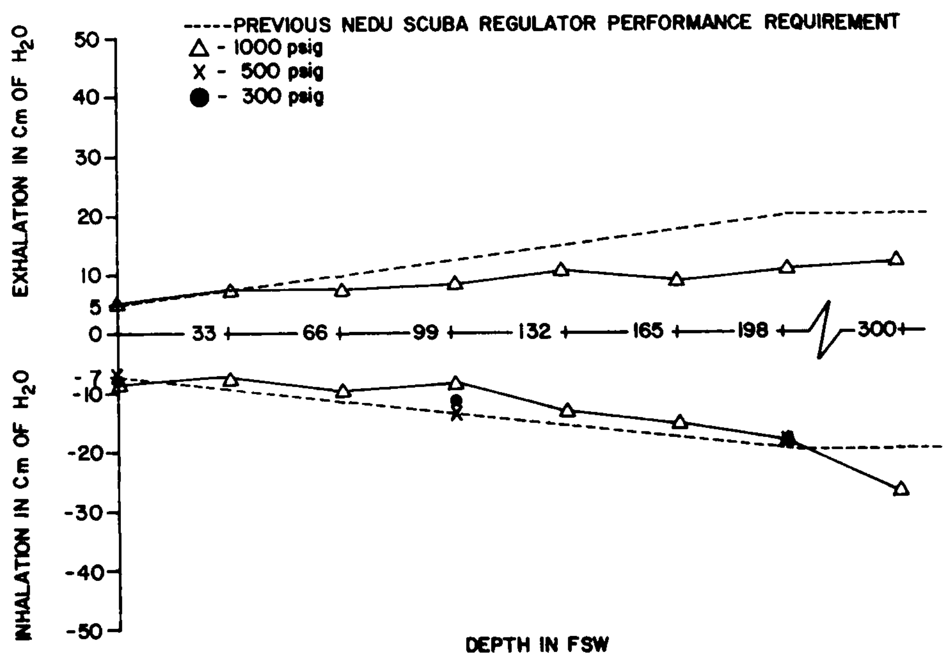

Figure 14A-2. White Stag Deep V
Breathing resistance vs. depth at 40 RMV

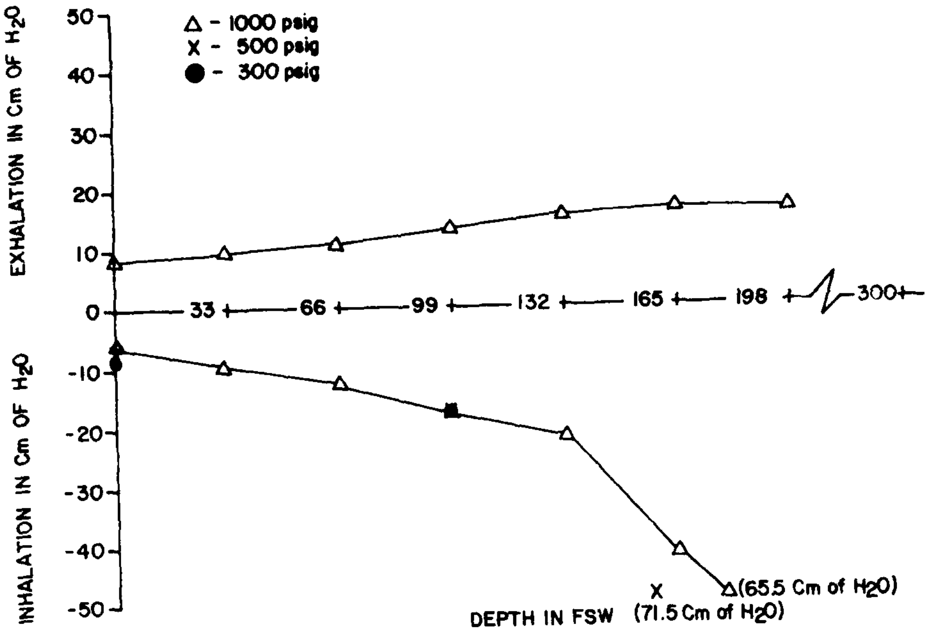

Figure 14A-3. White Stag Deep V
Breathing resistance vs. depth at 62.5 RMV

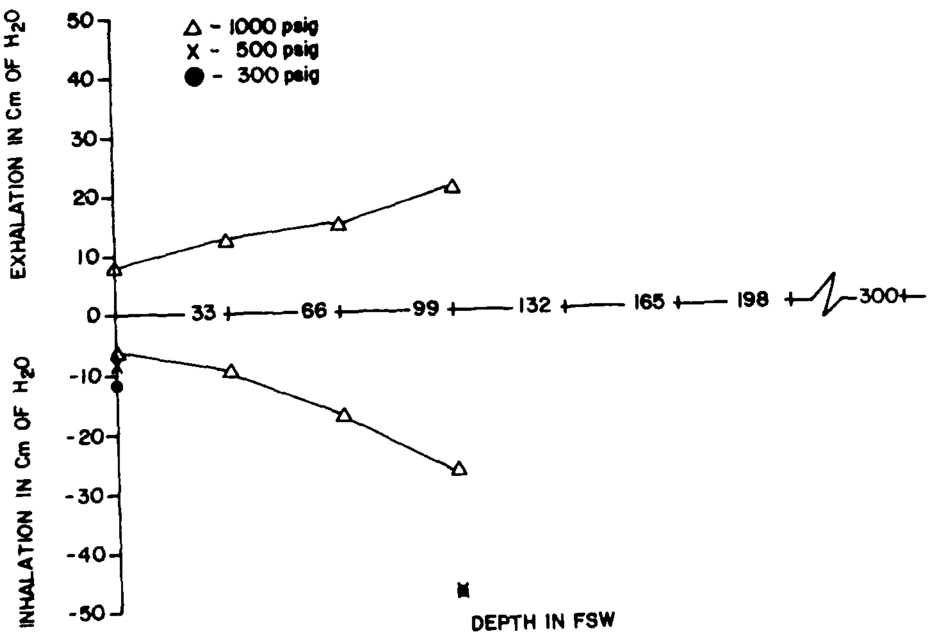

Figure 14A-4. White Stag Deep V
Breathing resistance vs. depth at 75 RMV

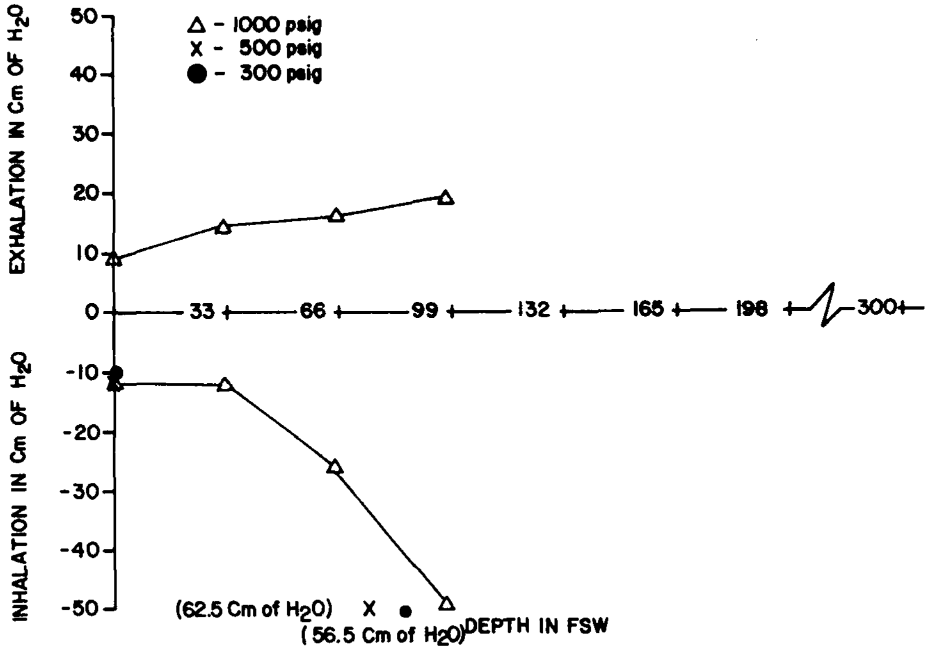

Figure 14A-5. White Stag Deep V
Breathing resistance vs. depth at 90 RMV

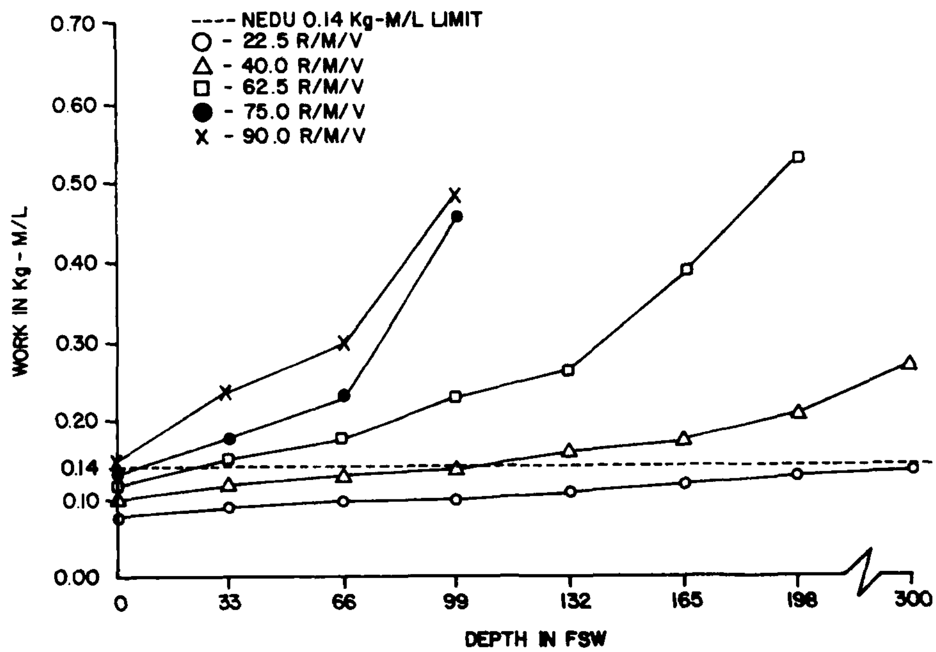

Figure 14A-6. White Stag Deep V
Breathing work vs. depth at 1000 psig supply pressure

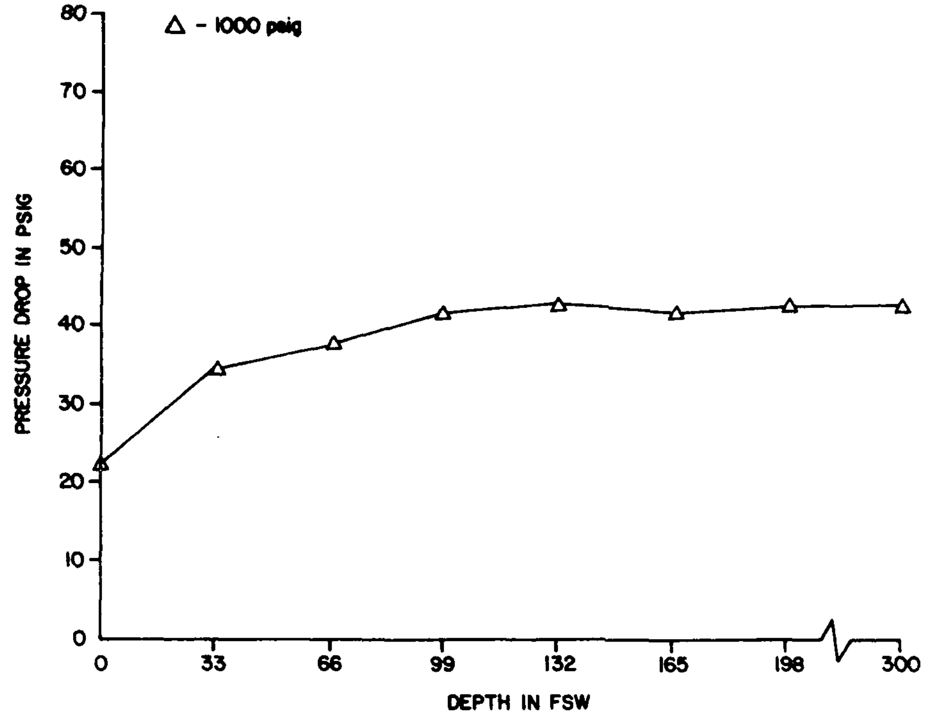

Figure 14A-7. White Stag Deep V
First stage pressure drop vs. depth at 22.5 RMV

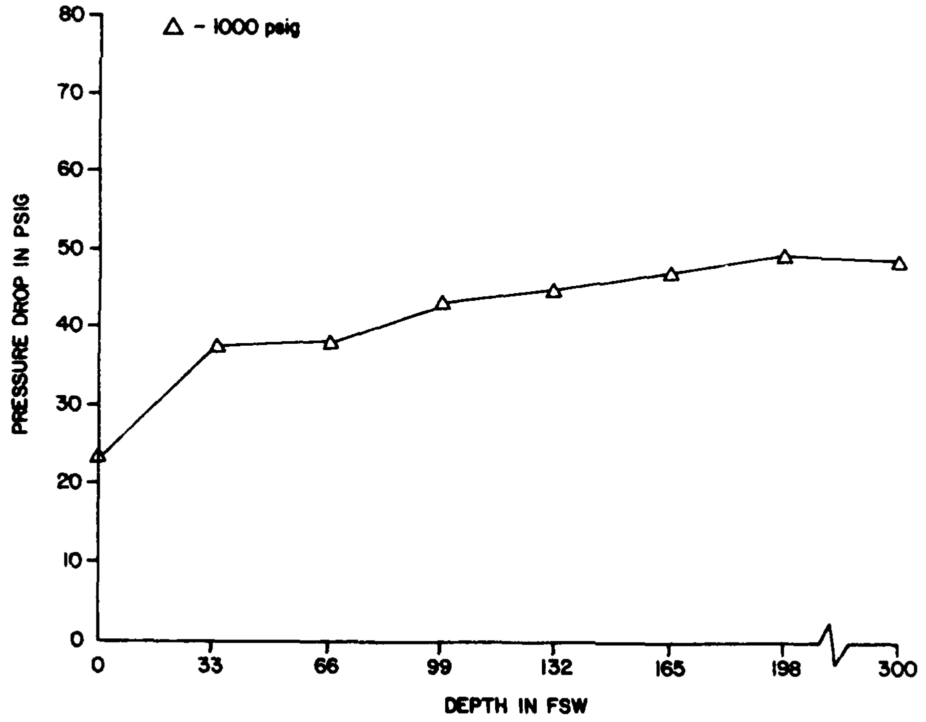

Figure 14A-8. White Stag Deep V
First stage pressure drop vs. depth at 40 RMV

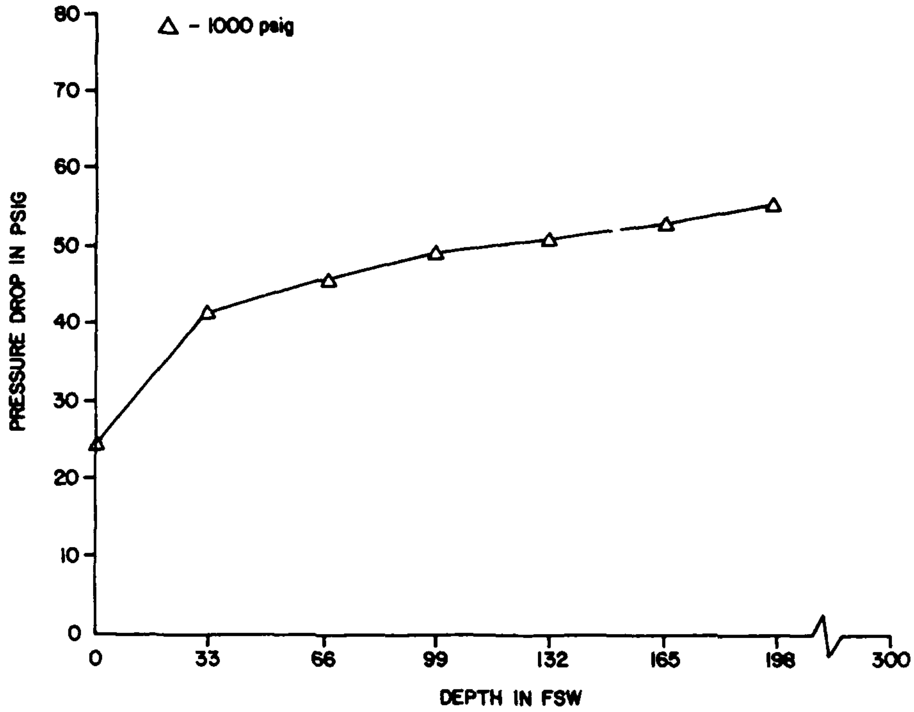

Figure 14A-9. White Stag Deep V
First stage pressure drop vs. depth at 62.5 RMV

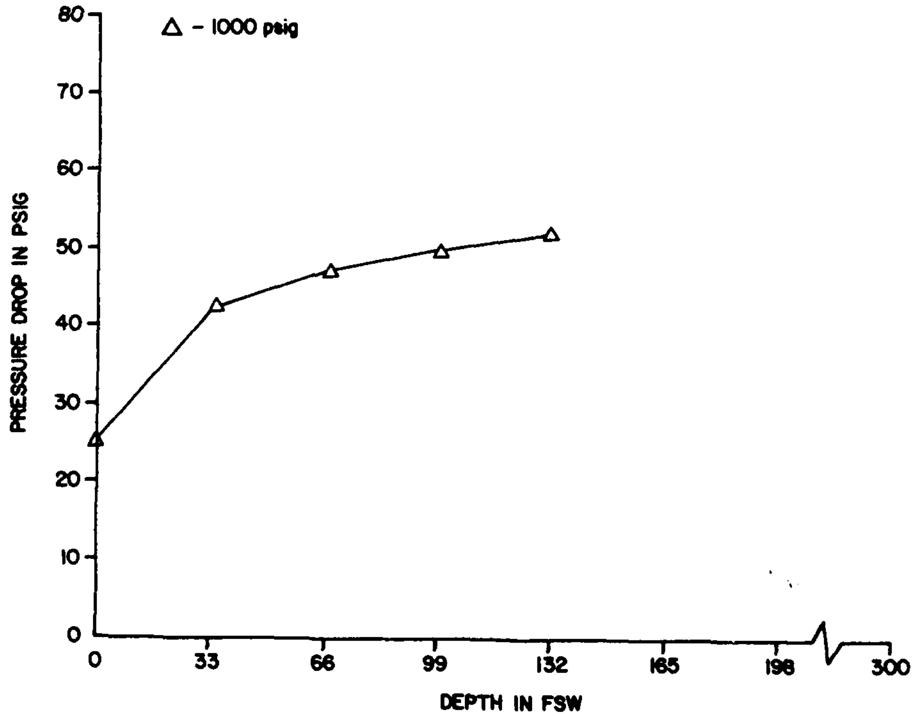

Figure 14A-10. White Stag Deep V
First stage pressure drop vs. depth at 75 RMV

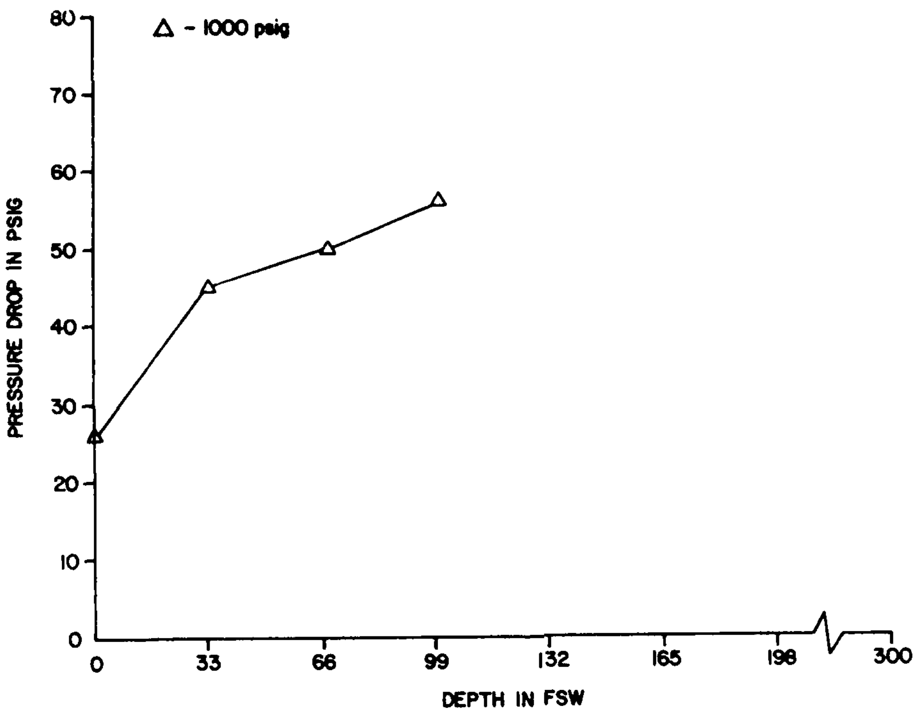

Figure 14A-11. White Stag Deep V
First stage pressure drop vs. depth at 90 RMV